METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 52 No. 311 SEPTEMBER, 1955 Monthly: TWO SHILLINGS

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INCORPORATING THE METALLURGICAL ENGINEER

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	Page
Steel Management Training	105
Statistical Methods in Metallurgy. By U. R. Evans	107–111
Abraham Darby. By E. N. Simons	112–114
Machine Casting Zinc Slabs	114
Electroplated Contacts. By P. Quinn	115–120
Modern Concepts in the Protection of Magnesium Base Alloys. By. W. F. Higgins	121–124
Quantity Production of Tractor Castings in Elektron. By W. J. Sully	124–126
Machine for Fatigue Testing of Electrical Cable	127–128
The Structure and Mechanical Properties of White Irons. By W. J. Williams	129–134
Railway Axle Production—United Steel's New Forge	135–136
Titanium Alloy Production. New Melting Plant will Extend Jessop Facilities	137–138
Stud Welding on to Small Curved Surfaces	138–139
European Steel Pipe and Tube Industry	139–140
News and Announcements	141–143
Recent Developments	144–145
Current Literature	146

LABORATORY METHODS SUPPLEMENT

Vienna Microanalysis Congress	147–150, 153
Items of Metallurgical Interest at the Physical Society Exhibition	151–153
The Spectrochemical Determination of Magnesium and Beryllium in Aluminium Alloys Using a Rotating Disc Electrode	154–156

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

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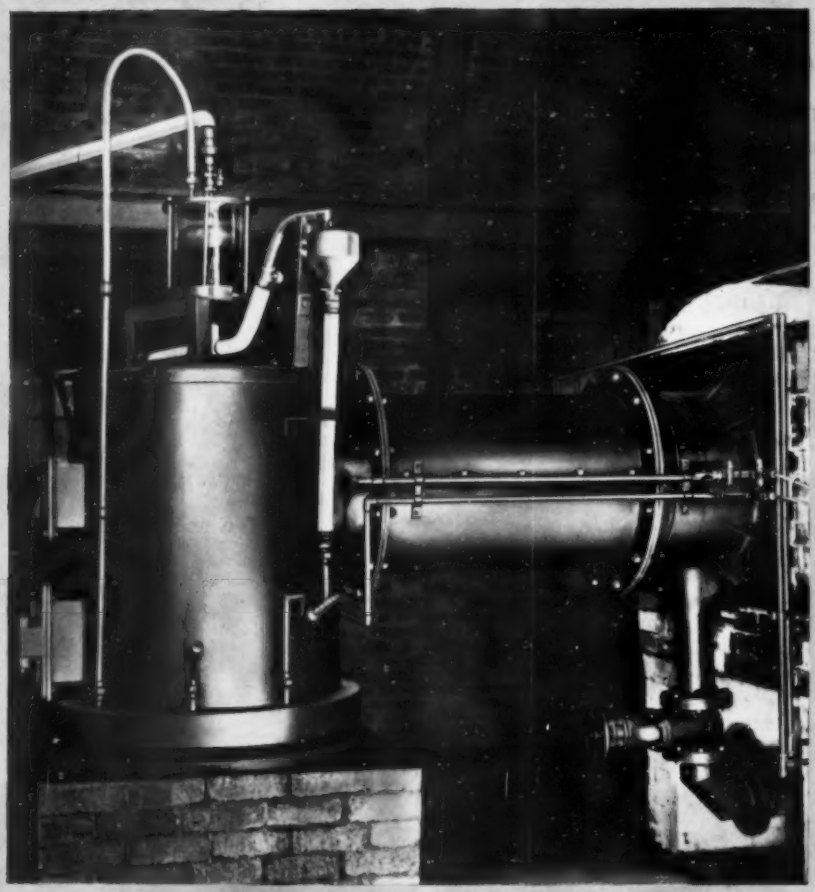

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SEPTEMBER, 1955 Vol. LII. No. 311

Steel Management Training

THERE was a time when the iron and steel industry found most of its managers from amongst those who joined it directly from school and started on the shop floor. More recently, some of them have been recruited from those entering at a later age, as technical or graduate apprentices, who showed that they possessed the necessary qualities and personality to warrant promotion. These men received a largely technical education and learned the art of management "on the job."

Such training is no longer equal to the present day demands of the industry, and three factors have contributed to make it necessary for future managers to receive a more systematic training. In the first place, the industry's development plans call for a large number of trained managers, and for higher standards at all levels of management. Secondly, the increasing complexity of many processes, and the consequent need for an increased number of specialists, has materially altered the function of the departmental manager, in that, instead of relying on his own experience, he frequently has to assess the advice of others: furthermore, the increasing integration of processes has necessitated his having a greater working knowledge of the operation of the whole works than was formerly the case. Lastly, the tempo of modern industry and the need for the highest productivity have increased the importance of making the best use of time spent on training, while changes in the educational system have radically affected not only the sources from which future managers can be drawn, but also the age at which they enter the industry.

To find and train suitable men for management is the constant concern of every company in the industry, and the British Iron and Steel Federation has recently published the report of a sub-committee of the Training Committee of the Federation, set up "to examine present and prospective arrangements for education and training for management in the iron and steel industry, with special reference to facilities for advanced studies of technical management subjects, and to make general recommendations."

The first essential of any training scheme is a satisfactory means of selection of suitable trainees who are likely to make the grade. The changes in the educational system since the war will tend increasingly to encourage the boy of above average ability to stay on at school and, if intellectually outstanding, to go onto a university. This means that industry must adjust its recruitment policy, for, although there may still be men entering the industry at 15 or 16 who have the characteristics required in a manager, it is expected that these will be fewer in number than was formerly the case. As far as individual companies are concerned, selection will be based on a systematic estimate of the company's future requirements, and managers must at all times be on the lookout for men with the necessary qualities who have been overlooked by the normal selection procedure.

The report stresses the importance of the policy of recruitment and selection, and the methods of training and education being widely understood within the company, and of their being flexible enough to deal with the late developer, since, although the changes in the educational system and the provision of more systematic training at all levels will ensure that every boy, whatever his social background, has a better opportunity than in the past to rise as far as he is able, a lack of knowledge of the may lead to the misapprehension that a privileged facts group is being created.

A number of recommendations are made on aspects of training and education, the value of co-operation between companies and universities in planning vacation training of students in such a way as to give them useful practical experience, including manual labour, is stressed. For those in the industry selected for management training, the use of residential courses is advocated, since the opportunity to mix with men from other departments and works not only broadens a man's knowledge but makes him look critically at his own ideas and practices. The suggestion is made that the Federation should organise, on a national basis, a series of experimental courses for suitable men with the necessary experience. While the syllabus would require to cover current problems facing the industry, and should include a critical examination of techniques applicable to the work of a manager, the method of work would be of prime importance, since the basic object would be to develop the man as an individual, rather than to provide him with a mass of factual information. Reference is also made to the value of sandwich courses, and to the importance of the active co-operation of the industry in the organisation of these and part-time courses.

It is important that the management should take an active part in any training scheme of this type, and one of the company's senior executives should be generally reponsible for ensuring that satisfactory training and education programmes are prepared and followed. All managers shold realise that one of their most important responsibilities is the development of those placed under them for training, since, not only do they owe a duty to the company to ensure that really well-qualified successors are available, but their own prospects of promotion may be impaired if there is no one to take their place. A man can learn a great deal from observing a good manager, but he can learn even more if that manager accepts the responsibility for constantly watching his work and discussing it with him. An intelligent man should not have difficulty in acquiring the knowledge required to become a manager, but good personal coaching can speed up the time it takes for him to learn how to select from this knowledge, and how to apply it to the daily work he is doing.

International Powder Metallurgy Society Formed

DURING the International Seminar on Powder Metallurgy, held in Reutte in June, the representatives of fourteen nations recognized the necessity of a closer co-operation and formed the International Plansee Society for Powder Metallurgy—an international organization for the promotion of powder metallurgy.

The purpose of the new society is : (*a*) to promote a better understanding and exchange of ideas among powder metallurgists in Western countries ; (*b*) to have international meetings to be held at Plansee, Reutte, every two to three years ; (*c*) to prepare a powder metallurgy dictionary with the terminology and explanations of powder metallurgy terms in the English, German and French languages ; and (*d*) to translate and distribute important articles in the field of powder metallurgy into the languages of the national sections.

Professor Gustav F. Huettig, world-known scientist in the field of powder metallurgy, was elected President of the new Society, Dr. Henry H. Hausner, Vice-President, and Dr. F. Benesovsky, Secretary. Powder metallurgists interested in joining the new Society should contact one of the above mentioned members of the Executive Board for further information. Their addresses are : Professor Gustav F. Huettig, Technische Hochschule, Rechbauer Strasse 8, Graz, Austria. Dr. Henry H. Hausner, Atomic Energy Division, Sylvania Electric Products, Inc., Bayside, New York, U.S.A., and Dr. F. Benesovsky, Metallwerk Plansee, Reutte (Tyrol), Austria.

Improved Molybdenum—Base Materials

STABLE oxides of certain metals dispersed in molybdenum produce compositions with greater creep strength than those of conventional molybdenum alloys, Battelle Institute, Columbus, Ohio, has found. Using powder-metallurgy methods, Battelle metallurgists have created molybdenum oxide compositions with creep lives more than twice as long as those of ordinary molybdenum alloys at temperatures of 1,800–2,000° F. (980–1,090° C.).

This improvement in creep strength—or the ability to withstand high stresses at elevated temperatures without deforming—was accomplished without altering the room-temperature properties of the molybdenum. Most effective strengtheners among the oxides studied were the hard, stable, insoluble oxides of zirconium, titanium, and chromium. Battelle experiments on the conventioual alloys of molybdenum, made by powder-metallurgy methods, showed that those made with silicon, chromium, aluminium, and tungsten have the best creep lives at temperatures of 1,800° F. (980° C.).

The research on the creep properties of molybdenum compositions was reported in a paper prepared by W. L. Bruckhart and Dr. R. I. Jaffee and presented at the annual meeting of the American Society for Testing Materials at Atlantic City, New Jersey, at the end of June. Outstanding among oxide additives were zirconium oxide and titanium oxide, while silicon was the best alloying metal. At 1,800° F.(980° C.), some of the oxide additions increased the 100-hour creep rupture strength of molybdenum almost fourfold. According to Jaffee, present research at Battelle suggests that further increases in molybdenum creep life may well come from compositions including both metallic and oxide additions.

When molybdenum alloys are exposed to elevated temperatures, they need protection against oxidation. For that reason, the research also included experiments on the effects of cladding materials on creep properties. It was found that nickel cladding has no effect on creep life. A protective coat of nickel limits total elongation of molybdenum parts to between 7% and 9%, somewhat lower than for unclad molybdenum. This amount of ductility, however, is still sufficient for most high-temperature applications.

Monel Jubilee

THE year 1955 marks the fiftieth anniversary of the production by International Nickel of the first of its series of versatile high-nickel copper alloys made and marketed by the trade mark Monel. The first alloy to which this trade mark was applied contained about two-thirds nickel and one-third copper, and was originally produced as a " natural " alloy from the ore of Inco's Creighton Mine in the Sudbury District of Ontario. The alloys owe their origin to the late R. C. Stanley, a former Chairman and President of International Nickel, and the trade mark applied to them was adopted from the name of the late Ambrose Monell, the patentee of the original method of manufacture, who at the time of the discovery and early development was President of the Company.

The initial Monel alloy was the pioneer that led to the development of many of the more than fifty nickel alloys which the Company now produces. In the first fifty years of production, nearly 900 million pounds of the Monel alloys were shipped to a wide variety of civilian and defence industries. This total could have been considerably greater if the unprecedented requirements for defence and stockpiling, particularly in recent years, had not necessitated diversion of nickel from many normal industrial channels.

A monument to the usefulness of the Monel alloys is Inco's Works at Huntington, West Virginia, built in 1921–22, specifically to produce the original Monel alloy in the many shapes and forms required by industry. This plant has been expanded until today, it is the largest in the world devoted exclusively to the production and fabrication of high-nickel alloys. At the Huntington Works Open House, October 25th–27th, the Monel anniversary will be observed.

Automation Conference Report

THE full report of the Margate Conference on " The Automatic Factory—What does it mean," will be available shortly. Members of the Conference will receive one copy free of charge ; other copies will be available to members and non-members at 25s. each, post free. The report, which will be in book form, will contain not only the papers presented at Margate, but also the opening and closing addresses, the discussion group reports, and a review of the display of automation equipment. This is the first published symposium dealing with the automatic factory and its many implications, and there is already a considerable demand for it. Orders and remittances should be addressed to the Publications Department, Institution of Production Engineers, 10, Chesterfield Street, London, W.1.

Statistical Methods in Metallurgy*

By Ulick R. Evans, Sc.D., F.R.S.

University of Cambridge

Statistical considerations are useful in metallurgy in deciding whether a series of values, which appear at first sight to show that some mechanical property is influenced by a constituent or a treatment, can be regarded as affording valid evidence for such a conclusion. They also show that in certain conditions "reproducibility" of results cannot be expected. Where it is difficult to spare time and material to obtain the number of measurements which is really desirable, it is important to choose methods of expression which make economical use of the data available, and the histogram and other graphical representations are discussed in this article.

THE author is not a professional statistician. He has, however, been interested in probability for about 50 years, has read something of probability and statistics and has given considerable thought to certain aspects of both subjects—which he has also discussed with friends. He has never at any one time been knowledgeable on more than a small part of the subject and, strictly speaking, is unqualified to lecture on "Statistical Methods in Metallurgy". He has, however, felt disturbed about some statistical papers lately published in metallurgical journals, and when he received an invitation to speak on the subject to a joint session of the Industrial Applications Section of the Royal Statistical Society and the London Section of the Institute of Metals, he gladly accepted the opportunity for some constructive criticism.

The methods set forth in the statistical textbooks often demand a large amount of data. The experimental metallurgist has neither the time nor the required number of specimens to make all the observations desirable for definite conclusions. He should, therefore, use methods which make the most economical use of such data as is available to him ; such methods are, however, not always chosen today.

Validity Tests

One type of statistical problem met with in metallurgy concerns the validity of tentative conclusions drawn from studying a number of measurements of some property in a series of materials within which some element or some treatment is continuously varied ; such problems are solved by the calculation of correlation coefficients and similar functions. In problems of slightly different types, the t-test, the x^2 test and other related tests are appropriate.

Let us consider a series of specimens of some alloy in which, say, the sulphur content steadily increases. A mechanical or chemical property is accurately measured and the numbers *seem* to show a general tendency for that property to rise (or to fall) as sulphur increases, but there are inconsistencies and, when the property is plotted against sulphur content, the points do not fall on a smooth curve. "Common sense"—often appealed to by those who despise statistics—gives no real help, since, of two sensible people who are asked to give judgment in the matter, one will say : "I think that the property is *tending* to rise with the sulphur content", whilst the other will say : "The numbers seem to run just anyhow."

The correlation methods of statistics give an answer which, if not absolutely definite, is at least objective. We adopt provisionally the hypothesis that, in point of fact, the fluctuation in the property has nothing to do with the progressive increase in the sulphur content, but is due to the play of chance ; it is clear that a number of specimens with identical sulphur content would, in fact, show different values of the property, and that, in a series of varying sulphur-contents, the values of the property might sometimes happen to arrange themselves roughly in the order of the sulphur content. It is not difficult to evaluate the chance of this occurring. If the chance is found to be very small, we must reject the hypothesis as improbable, and adopt the alternative view —namely, that the movement of the property in one direction as we pass along the series has at least *something* to do with the continual rise in the sulphur content.

Interpretations of Correlation Data

To say that the movement of the property has something to do with the sulphur content is not the same as saying that sulphur is the *cause* of that movement. Perhaps they both arise from a common cause. If the materials have not been specially made for the research, but have been obtained from odd stocks of commercial material in store, then (if sulphur is an undesired ingredient) a high sulphur content may indicate lack of care in production. Now lack of care in one respect often goes with lack of care in other respects. Thus, other unwanted features may be expected in the high-sulphur samples, which may well have come from a firm which was careless about enforcing correct conditions of heat treatment, or which provided poor storage conditions.

Or, again, high sulphur content may be associated with high contents of some other element. In segregated steel, the parts rich in sulphur are often those rich in phosphorus. If phosphorus possesses some desirable effect on mechanical properties and high-phosphorus samples are also high-sulphur samples, a series of sulphur determinations studied in relation to the values obtained on mechanical testing may *seem* to indicate that sulphur is *causing* good mechanical properties. This might induce someone to try to improve properties by intentionally adding sulphur to low-sulphur material—with disappointing results.

Calculation of the correlation coefficients, with the various orders of partial coefficients, enables the metallurgist, not only to ascertain whether the tendency of the property to move with the sulphur content is a genuine one, but also whether it is caused directly by the sulphur

* Based on a lecture delivered at a joint session of the Royal Statistical Society (Industrial Applications Section) and the Institute of Metals (London Section) on May 6, 1955.

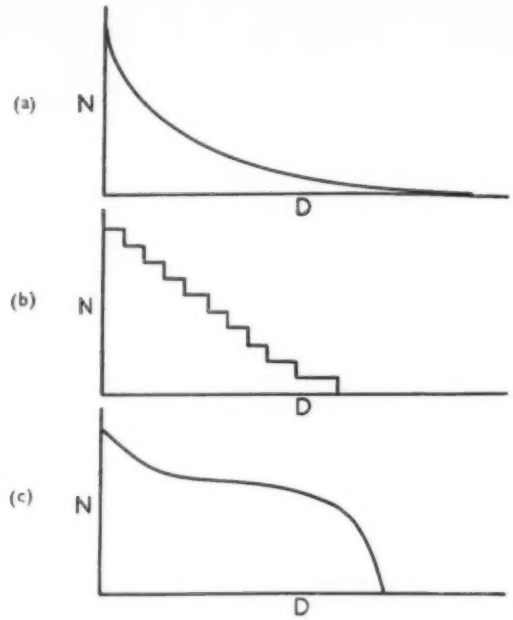

Fig. 1.

content, or, perhaps, by something correlated with the sulphur content. There is no need to describe the methods: they will be found in the books, and—what may be even more helpful—several examples exist in metallurgical literature where these methods have been used to obtain real information regarding the effect of elements. The writings which the reader is recommended to consult are those of Hoar[1] and Mears[2]. The authors' more detailed opinion of the correlation coefficient and of the t-test will be found elsewhere[3].

Irreproducibility

In certain types of research, an experiment repeated many times gives different results. The experimenter sometimes feels that, it he fails to get the same result each time, there must be something wrong with his instrument or his observations. This may not necessarily be the case. Indeed, in certain classes of work, any claim to perfect reproducibility would throw the experimenter open to grave suspicion.

Consider corrosion experiments on specimens of size 1 × 1 cm., exposed to corrosive liquid capable of producing (on the average) one corrosion centre on every 1 sq. mm.; then the "expected" number of centres on each specimen will be about 100, and—provided that one active centre does not interfere with the activity of others by "mutual protection"—we should get numbers on each specimen not far from 100 (they would probably be ranged around that value according to the Poisson distribution). By adding an inhibitor to the liquid, we can reduce the number of centres to 1 in 1 sq. cm. or, with still larger amounts of inhibitor, to 1 in 1 sq. dm. In the latter case, we cannot possibly hope for reproducibility, since now the "expected number" is only 0·01 on each specimen, so that it is likely that 99% of the specimens will show no corrosion at all, whilst about 1% of them will have one centre apiece (the chance of two centres per specimen is too small to need consideration. In the intermediate case where the expected number of centres is 1 in 1 sq. cm. (that is, one per specimen), we might perhaps hope for exact reproducibility—each specimen showing exactly one corrosion centre. However, the Poisson distribution predicts that 36·8% will have no centres, 36·8% one centre and 26·4% more than one centre. Mutual protection should not affect the accuracy of the prediction of the proportion showing no corrosion at all, but it may cause an adjustment of the last two numbers, reducing the proportion showing more than one active centre. Thus, the proportion showing exactly one centre should exceed that showing no corrosion at all. Whatever the exact numbers obtained, it is evident that irreproducibility is no proof of bad control or faulty measurement, and there is no reason for anyone to be ashamed of it.

Clearly, no importance can be attached to a single experiment in such cases. If, however, experiments can be repeated a sufficient number of times to afford measure of the probability P_A of escaping corrosion entirely on specimens of area A, the "expected number" of corrosion centres E on unit area, in the absence of mutual protection, is obtained by the equation

$$P_A = e^{-AE}$$

Having once obtained the value of E, we are in a position to calculate the probability of escaping corrosion on any larger area.* Clearly the prospects of such an escape become increasingly small as the area becomes larger, and this should never be forgotten in applying the results of laboratory work on small specimens to predict the behaviour of materials in full scale plant.

There are, however, certain cases where, at first sight, we should expect behaviour to be irreproducible, and also dependent on size, but where in point of fact the reproducibility is found to be fairly good and the size-dependence only slight. One such example may now be considered.

Use of Extreme Values as a Criterion

Let us consider the distribution of pit depths on a corroded pipe. It is usual to record the depth of the "deepest pit" on a sample as a measure of the aggressive quality of the soil, or of the susceptibility of the steel to corrosion. Is it a good measure?

If the frequency of different values of the pit-depth D, as obtained from a study of a specimen of *infinite* size, is represented by a smooth curve approaching zero asymptotically (Fig. 1*a*), then it is clear that measurement of the depth of the deepest pit performed on specimens of *finite* size would vary from specimen to specimen—suggesting that pit-depth is an unsuitable criterion. For any *individual* specimen must show a *stepped* curve (Fig. 1*b*), the steps occurring at the depth of the deepest pit, the second deepest pit, the third deepest pit and so on; yet all the stepped curves when superimposed must blend to form the smooth curve, which blending can only occur if the last steps (representing the deepest pit on individual specimens) occur at different depths on different specimens. Similarly, for cases with an asymptotic approach to zero, a large specimen will usually show a much greater depth-value for the deepest pit than a small specimen.

* If AE is the "expected number" of corrosion centres on area A, the probability of obtaining n centres is given by Poisson's formula $e^{-AE}(AE)^n/n!$. The formula neglects "mutual protection"—i.e., the fact that corrosion at one point depresses the probability of corrosion at points around it. This will often invalidate the calculations on cases where n is one or more, but not when $n=0$; in that special case, the formula reduces to e^{-AE}.

Those who use such a method sometimes assure us that it is a sound one, since there is in fact no serious divergence between the depth of the deepest pit present on different specimens. This need not be rejected as absurd. Indeed, such a situation is to be expected if the distribution curve, instead of approaching the axis asymptotically, cuts it at a sharp angle (Fig. 1*c*), so that there is a certain depth which, in a given time of exposure, is never exceeded ; there is nothing impossible from the chemical or electrochemical standpoint in this assumption. If the gradient of the curve is sufficiently near the vertical, then not only may we expect fairly good reproducibility between specimens of the same size, but the size of the specimen (provided it be not too small) will have comparatively little influence on the results. It is only in such cases that the depth of the deepest pit constitutes a sound criterion—and this shows how important is the study of distribution data.

Histograms and other Distribution Diagrams

Many other problems which confront the metallurgist involve the use of distribution diagrams. First it is necessary to discuss the present tendency to use " histograms " in the place of smooth " distribution curves " in the graphical expression of data. It is believed that the cult of the histogram is today involving much waste of valuable data and introducing unnecessary uncertainty.

The histogram is doubtless a useful kindergarten device for presenting the idea of statistics to a beginner. There are also occasions where the numbers of specimens falling within *finite* ranges possess real interest, and in such cases a histogram can be regarded as a rational method of presenting the data ; examples are common in vital statistics and educational enquiries, where division into sharply defined age-groups is justified on the grounds of convenience.

In certain other cases, where the numbers of specimens is large, the histogram representation may have its convenience for some purposes, and it seems to appeal to certain types of minds. But it is being used today in cases where the data is scanty ; indeed a histogram was recently published, in a reputable journal, based ostensibly on 23 points—although it is understood that additional evidence existed and was taken into account.

Consider a large number of specimens intended to be all alike so that they *ought* to possess, say, the same strength; actually, they differ slightly—possibly owing to variation of composition or surface defects—and their strengths vary. Suppose that there has only been time (or material) to test to destruction 24 specimens, and we wish to use the 24 values to obtain some idea—necessarily vague—regarding the distribution of strength throughout the population. If we decide to use the histogram method, we may try dividing the range of strength represented into 8 different sections, and thus obtain 8 vertical blocks for our histogram. Since on the average we shall have only 3 values falling in each block, the heights of the blocks vary in big jumps and the result cannot be accurate. Alternatively, we can choose to have 6 blocks with 4 specimens per block, or again 4 blocks with 6 specimens per block ; then we obtain a greater accuracy for the block-height, but the number of blocks becomes too small to give an idea of the distribution curve.

The unsatisfactory character of the histogram method arises from the fact that it introduces inaccuracies and wastes accurate data. In constructing the histogram

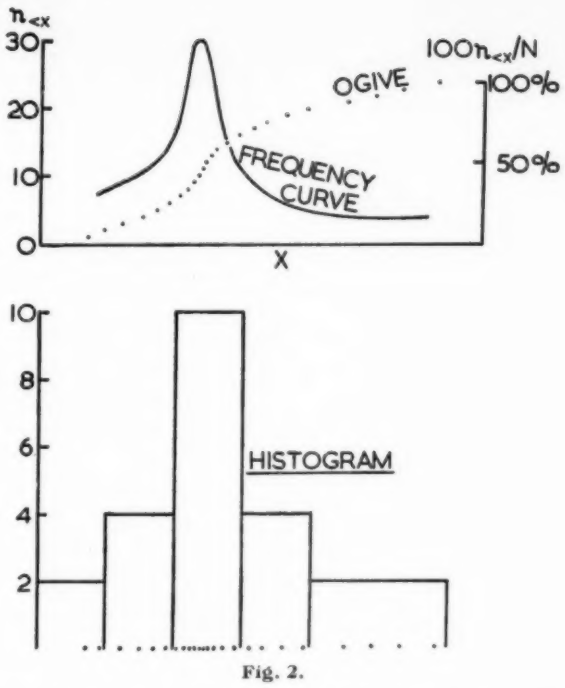

Fig. 2.

(Fig 2), we treat all the points within a certain range as though they had the same value—which is not the case. We also neglect the valuable information inherent in the position within the range. If the points situated in a block lie closer to the inner boundary than to the outer one, this fact receives no attention ; precisely the same histogram would be obtained if these points had lain near to the outer boundary. If thus we waste and vitiate our data, we cannot hope to derive the greatest amount of information.

The Ogive as a Representation of Data

Clearly a sample of 24 is insufficient to give a reliable idea of the distribution of " properties " in the population from which the sample was drawn—whatever method of representation is adopted. Nevertheless, if, abandoning the histogram method, we plot against the strength X the number of specimens $n_{<x}$ having a strength less than any given value of X, we have 24 points through which we can draw our curve. The curve will not pass exactly *through* all 24 points, but it will usually pass *between* them and fairly close to most of them ; the general course of the curve of best fit is not seriously in doubt, and some idea can be obtained of the probable course of the " true " curve (such as would be obtained from a very large number of specimens). Curves obtained from a small sample of 24 specimens—drawn by different people—will not be quite the same ; they will also differ appreciably from curves obtained from samples of 240 or 2,400 specimens, but the general shape should be at least similar in all cases. One method, adopted in Fig. 2, is to put in all the points, thus laying the whole of the data before the reader, and leave him to picture the curve for himself.

It is suggested that the ogive or cumulative curve thus obtained is a suitable and compact method of presenting the data—preserving much that is wasted or

distorted in drawing histograms. The facts are put in a form which demands no knowledge of calculus, since the ordinate represents the number of articles $n_{<X}$ possessing a strength (size or weight) less than some definite value; alternatively, the scale can be drawn to show the *proportion* of articles failing to reach this value ($n_{<X}/N$), where N is the number in the sample, and this is surely an idea which every schoolboy can understand.

Frequency Curves

If it is desired to obtain a frequency curve comparable to the histogram, but smooth and less wasteful of data, it is possible to differentiate, and plot $\frac{d}{dX}\left(\frac{n_{<X}}{N}\right)$ against X. Experience has shown that frequency curves thus obtained have given useful information in an industrial problem where the histogram method had proved useless[4].

The objection generally raised to such a procedure is that the differentiation, being necessarily graphical, must be inaccurate and non-objective; it is, however, believed that methods of graphical differentiation could be improved*. Another objection to the frequency curve is that it conveys exact information only to those conversant with calculus and used to thinking in terms of infinitesimals. The meaning of the frequency ordinate of the curve is best understood if we consider a curve representing the distribution of a very large number of specimens. If F is then the ordinate corresponding to an abscissa representing X, then the proportion of specimens with strengths (weights or sizes) falling between X and $X + dX$ is FdX; this is not a very elementary notion.

Calculation of Safe Conditions

Commonly the metallurgist's problem concerns safe conditions of service. "Safety" is a relative term, but the user desires to know the stress at which not more than one specimen in 100, or 1 in 1,000 or 1 in 10,000 will fail—according to the risk which he is prepared to accept. The method usually adopted is to determine the frequency curve by testing a number of specimens—all of them intended to be alike, but in point of fact different, since they break at different stresses. If now the experimenter can persuade himself that the distribution is *normal*, the rest is easy. The standard deviation σ is calculated, and the tables provide the answer. At a stress which is $2{\cdot}3\sigma$ below the mean value of the breaking strength, 1 in 100 specimens will break; at $3{\cdot}1\sigma$ below the mean, 1 in 1,000 will break, and so on. The simplicity of the method offers a great temptation for the person analysing the data to argue that the distribution is sufficiently near to normal to justify him in proceeding on these delightfully easy lines.

Such a method is often unsatisfactory, and may be highly dangerous. The points are usually too few to provide certain knowledge as to the true shape of the frequency curve representing the population. Curves have been published of late in reputable metallurgical journals based on only four or five points, and yet it has been claimed that they show the distribution to be "about normal", apparently without challenge from a referee or anyone else. Even supposing that the data is sufficient to establish with some confidence that the "humpy" part of the curve is normal, the assumption that normality can be assumed for the tail of the curve is equivalent to an outrageous extrapolation. It is quite clear that in many cases there must be departure from the normal at low values of the strength (or other variable), since a normal distribution assumes values ranging from $-\infty$ to $+\infty$, and negative values are usually devoid of physical meaning. The question arises, therefore; where does the departure from normality first become serious? The assumption that the departure only becomes serious at values lower than those which interest us is merely wishful thinking. The only way to be certain about the shape of the tail of the curve is to perform experiments in that region.

The usual test for normality is to plot $n_{<X}/N$ against X on special paper, with the scale distorted in proportion to $e^{3\cdot2\delta}$ (δ being the deviation expressed as a fraction of σ). On such paper, it is clear that, if the distribution is normal, a straight line will be obtained. The straight line would curl up into the normal ogive if the distortion of the scale were released so that the scale became "open", (every division then representing the same value).

In cases where all the points obtained from our experimental data on the special paper fall *exactly* on a straight line, a normal distribution can justifiably be assumed for that part of the curve represented by the experimental points. But where there is a small departure from the straight, it is wrong to assume that there is only a *small* departure from normality. It is not the linear distances of the erring points which matter, but the *angular* departure of the line which runs through (or close to) the experimental points, from the general slope of the straight line corresponding to exact normality; the ordinates of the frequency curve are obtained by differentiation of the ogive which appears after the distortion is released, and thus it is the *gradient* of the curve which is important. This aspect of the case is often overlooked.

Suggestions for Improved Procedure

In cases where the time and material are insufficient to allow statistical methods to be applied in a satisfactory manner, it would be honest to say so. However, in many cases where today statistical methods are being used to arrive at conclusions which cannot be accepted with confidence, the same time and material would give reasonably certain results—were they economically employed. For instance, the experimental data may have been sufficient to establish with reasonable accuracy the shape of the distribution curve, but the data has been frittered away in constructing histograms. Or, again, time may have been wasted in carrying out a small number of long experiments designed to define the course of the curve in a region which has no interest for us, whereas the same total time and effort devoted to performing a large number of short experiments covering the range which is of vital importance, would have served to provide relatively trustworthy knowledge of that region.

Such a policy would seem to suggest a solution of our difficulty for certain cases. It is recommended that all

* Obviously any attempt based on taking the gradient of a line "judged" by sight to be a tangent as an estimate of the differential is neither accurate nor objective. But the use of a transparent protractor ruled with two sets of parallel lines at right angles very close together should enable a mental arithmetician to calculate rapidly on a series of chords the ratio of chord-segments made by the normal passing through the point of touching. When the inclination is such that the ratio approaches unity as the chord-length approaches zero, the chords will be parallel to the true tangent.

results should be expressed as an ogive, but that only a few long-time experiments need be carried out to indicate quite roughly the shape of the " late " part of the ogive lying beyond the inflection point (corresponding to the mode of the frequency curve), since this remote region has no practical interest. In contrast, the earlier part of the ogive should be explored thoroughly, and since this calls for a large number of experiments, it would be permissible to stop each experiment where the specimen has remained unbroken for a certain time, liberating the machine for the next test. In this way, the early part of the ogive should be defined with some accuracy, and an equation should be sought which best fits all points, and which is a reasonable accord with past experience of testing other batches of material. This equation can then be applied to predict the stress likely to produce one break in 10^4, 10^5 or even 10^6. We thus obtain some idea of the sort of stress at which the risk does not exceed the accepted small value.

This procedure would seem to have two advantages over that adopted at present ; (1) admittedly the proposed method still involves extrapolation, (none the less real because is is performed algebraically, not geometrically) but it is extrapolation from points situated in a region far less remote from the region which concerns us than the extrapolation carried out in the customary procedure—so that the error is less ; and (2) since each experiment will be shorter, a larger number of experiments can be performed, and by concentrating on a limited part of the ogive, its form can be obtained with comparative confidence.

Use of Tchebycheff and Camp-Meidell Inequalities

In cases where there is no justification for assuming Normal Distribution, the adoption of one of the methods of more general application suggests itself. The so-called Tchebycheff Inequality states that

$$P_{u\sigma} \geqslant 1 - 1/u^2$$

where $P_{u\sigma}$ is the probability that an observation will lie within the interval $u\sigma$ from the mean. The statement is *valid for every sort of distribution*, but in the words of Kenney[5] " The gain in generality must be paid for, and the price is inadequate information about the particular. That is, the Inequality may be too wide to be of practical value in passing judgments." Davies[6] states that the Inequality will rarely be useful in chemical industry on account of its " conservative " character—and it is unlikely to be more generally helpful to the metallurgist.

The Camp-Meidell Inequality is less general, consequently less conservative and more likely to be useful. It is only valid if the distribution is continuous and unimodal, and if the skewness, is measured by (Mean–Mode)/σ (taken as positive), is less than 1·0. The Inequality states that, under these conditions,

$$P_{u\sigma} \geqslant 1 - 1/2{\cdot}25u^2$$

A comparison between the two Inequalities and the Normal Distribution is given in the following table, based on one printed in Davies' book.

Deviate (u)	1·0	2·0	3·0	4·0
Normal Law	0·6827	0·9545	0·9973	0·9999
Camp-Meidell	0·5556	0·8889	0·9506	0·9722
Tchebycheff	0·0000	0·7500	0·8889	0·9375

The figures show how worth while it is to establish definitely normality of distribution since, if distribution *really* normal, then, at $u=4$, the undesired event need only be expected once in 10,000 times. It also shows, however, how disastrous it may be to assume normality of distribution on insufficient evidence, since in the general (Tchebycheff) case, or even subject to the more lenient demands of the Camp-Meidell Inequality, much more frequent occurrence must be anticipated.

However, even in cases where the distribution is not normal, much can be done if once that distribution can be established. On this point Jones[7] writes as follows : " More care should be taken in establishing the form of the parent distribution. Apart from the normal, there are cases in which the extreme value distribution, or perhaps one of the Pearson curves, may be appropriate. When this has been done, confidence limits should always be associated with estimates of proportions falling below prescribed values. These limits are of course wider as the sample gets less. In this way I think it is possible to get useful and legitimate conclusions for design values of strength and so on ".

Accuracy of the Testing Method

However reliable the measuring device, and however careful the control, a number of measurements carried out on a batch of materal will represent vastly different values —owing to variation of the material or its surface condition. The idea seems to exist that scatter can be overcome by using more accurate testing machines or otherwise improving the technique, but this cannot, in general, compensate for an insufficient number of experiments. No doubt cases exist where improved machines might reduce the scatter ; Weibull[8] considers that in fatigue testing 40% of the variance is due to the machine. But to make the measuring instruments so accurate that the variance due to errors of measurement (such as would be obtained even if the specimens were truly identical) is small compared to the scatter due to variation in materials (such as would be obtained on an infinitely accurate instrument) represents a waste of money. In some cases, a more profitable plan would be to purchase a number of less refined, and therefore cheaper, machines, so that a much larger number of specimens could be tested simultaneously.

The matter has been discussed by the author elsewhere[9] and the two essential principles have been well expressed by Whyte[10] : (*a*) the more heterogeneous the product, the less reproducible need be the test used to measure it ; and (*b*) the wider the range of samples which can be covered by repeat experiments, the less is the need for a test of high precision.

Acknowledgments

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Abraham Darby

Pioneer of Use of Coke in Iron Smelting

By Eric N. Simons

The invention of the steam engine and the development of a process for the production of iron by smelting the ore with coke in the blast furnace, interdependent as they were, laid the foundations of Britain's industrial prosperity. In this article, the author is concerned with Abraham Darby, the first of a line of notable iron-makers at Coalbrookdale, where he first successfully used coke for smelting iron ore in the early eighteenth century.

THE first man to use mineral coal successfully in the production of iron was Abraham Darby. As Prof. Henry Louis pointed out in his interesting paper, 'The History of Iron Manufacture' (1925): "without Darby's pig iron it would have been difficult or impossible to produce the large quantities of iron that were needed for the manufacture of the steam engine and its numerous applications."

Darby's furnace was at Coalbrookdale, and his first attempt to use mineral coal was in the year 1713. It was 1735 however before he achieved complete success, when he made cast iron with coke 'in the high furnace' (i.e., the blast furnace). In *Philosophical Transactions*, Vol. 14 (1747), one may read that 'Mr. Ford, from iron and coal both got in the same Dale (Coalbrook), makes iron brittle or tough, as he pleases; there being cannon thus cast so soft as to bear turning like wrought iron'.

Decline in Iron Production

The condition of the iron-producing districts of England at this period in her history is of considerable interest. The steady decline in the production of iron which had followed the failure of Dud Dudley in his attempts to utilize mineral coal in the smelting of iron, had led to a decrease in the value of the extensive woodlands covering the country, many of which were reserved almost exclusively for the use of the iron manufacturers. In consequence, the utilization of land for agricultural purposes had increased, and as agriculture became increasingly profitable, so great tracts of woodland were broken up and devoted to cultivation. This was particularly the case where the forests had had inroads made into them in previous decades, by those who sought to make charcoal from their timber for use in the blast furnace. A superficial observer studying England at that time, and marking the continual encroachment of the agriculturalist upon the woodlands, would have concluded that before long England would cease to function as an industrial nation, and that her exports, as with other small countries at the present day, would henceforward consist primarily of agricultural produce.

Two discoveries gave a new impetus to Britain's declining industries and the use of her natural resources. One was Abraham Darby's discovery, and the other the introduction of the steam engine, which, by enabling the blast for the blast furnace to be mechanically produced, gave fresh life to the iron trade and led to progressive improvements and developments of which we have yet to see the end.

How greatly the iron industry had diminished in importance is made evident by the fact that the 300 blast furnaces mentioned by Dud Dudley as in operation in his day had dwindled to 59 in operation in 1740. These had a total annual output of 17,350 tons as against a yearly aggregate of 180,000 tons in 1613. Of this comparatively small quantity of 17,350 tons, Yorkshire produced 1,400 tons from 6 furnaces; Sussex, with 10 furnaces, produced only the same amount. Gloucestershire, with 6 furnaces, produced more than double Yorkshire's tonnage, namely, 2,850.

Naturally, this production was inadequate to meet the needs of the country, so that large quantities of iron were imported, mostly from Russia and Sweden. Between 1720 and 1735, over 25,000 tons were imported, on average, each year, as against average yearly exports of something over 5,000 tons.

The Coalbrookdale works were founded in 1709. In the 17th century Coalbrookdale formed part of Sir Basil Brook's estate. In the last decade of that same century, two furnaces, together with forges, were leased to Shadrach Fox, and from him by sub-leases they came into the possession of Abraham Darby. Abraham Darby himself was the direct descendant of a line of yeomen-smiths, and was born at Sedgley, near Dudley, in the year 1676. These yeomen-smiths combined the practice of agriculture with the manufacture of nails, locks and similar articles. In his boyhood, Darby showed a mechanical bent, and, when he became old enough, was apprenticed to a maker of malt-mills in Birmingham. At the age of twenty-three he settled down in Bristol, and, in combination with a number of friends, set up a small works for the manufacture of iron and brass articles at the Baptist Mills. Here he started experimenting in the substitution of cast iron for brass in the manufacture of small objects.

Dutch Labour

The great exponents of the metallurgical art at that period were the Dutch, who were favoured by external circumstances, such as lower duties and cheaper labour, but they also possessed superior skill in the casting of iron. As a result, Darby, dissatisfied with the labour at his disposal, went over to Holland in 1704, and returned with a number of trained Dutch iron workers. Associated with him at this time was John Thomas, originally a shepherd. Three years later the partners took out a patent entitled: 'new invention of casting iron bellied pots and other bellied ware in sand only without loam or clay.' This patent, the result of the combined experi-

ments, was considered by Professor Ashton to consist of either a special casting box or a new method of preparing the moulds. It must be remembered, in this connection, that Darby did not invent the sand-casting process. The statement that he made the first cast iron pots in England is founded on a misunderstanding.

Shortly afterwards, Darby dissolved partnership with Thomas, and joined James Peters of Bristol and Griffin Prankard of Somerton, for the purpose of erecting an iron works in Cheese Lane. In 1708 he took up a lease of the Coalbrookdale furnaces.

Darby, of course, was not the first to produce coke. As early as 1627 there is a record of a patent for a process to achieve this end, and similar patents cropped up at intervals during the succeeding years. It is known, however, that coal was *coked and actually used in the blast furnace* at Coalbrookdale at least as early as 1718. Darby left behind a ' Day-book ' or ' Diary ', known as his ' Blast-Furnace Memorandum Book ', which records the principal transactions at Coalbrookdale from the time of the lease onwards. From this it can be learned that his favourite furnace charge was five baskets of coke, two of brays and one of peat, these being followed by the ore and limestone. Turves and stacks of coke existed at both furnaces ; but the most convincing item of evidence is the record of extensive and *regular* purchases of coal almost from the first day of the concern. The following two entries out of many similar ones are significant :

1709		£	s.	d.
July 22.	Richard Hartshorn & Co. By Cash paid E. Dorrell pr. theyer order in part for Coles.	08	04	06
Sept. 6	By Cash paid Edward Dorrall for Coles	05	18	11

There is no record that the coal bought was sold by Darby to others, and as he did not produce any finished goods made from wrought iron, it is obvious that the coal he bought was not for use in the smithy. Some may have been consumed raw, but the following entries show that much of it was actually coked and used in the furnaces.

1709		£	s.	d.
Apr. 20th.	By Cash paid for Charcking Coles ..	00	01	03
Apr. 24th.	By Cash pd. Edward Dorall for coling (coking) Coles	01	12	4
July 2.	Lawrence Woling. By cash pd. him in part for Coles and Iron wheald ye first blast.	30	00	00

On the other hand, there are scarcely any indications that charcoal was used for smelting purposes, and it is, therefore, reasonable to suppose that the greater part of the fuel used by Darby in his smelting furnaces was of mineral type.

Ten Tons of Iron a Week

From 5 to 10 tons of iron a week appear to have been made at Coalbrookdale, the principal products being pots, kettles and other hollowware, cast direct from the furnace. The remaining metal was run into pigs. In course of time other castings produced included grates, smoothing irons, door frames, weights, baking plates, cart bushes, iron pestles and mortars, and occasionally a tailor's goose. The business grew until eventually as many as 150 pots and kettles were cast in a week.

Darby did not introduce any special flux into his furnace, since the records show that he used lime. At one time there was some doubt whether Abraham Darby was the first to discover the process associated with his name, and some historians believed that the date of the discovery was later than 1713, and owed its origin to his son or grandson, for Darby founded a noteworthy line of ironmakers at Coalbrookdale. Later research has, however, clearly established that the first Abraham Darby was the pioneer.

The difficulty in assigning an exact date to the discovery arose, no doubt, from the large number of failures that would inevitably occur, and the lack of continuity in the successes. Darby himself was probably never certain how each lot of iron would turn out after the smelting operation. The varying quality of the coal employed would also exert an important and fluctuating effect on the iron. The doubt cast upon his authenticity as the pioneer arose from the fact that his process is not mentioned in many contemporary records of iron-manufacture in other parts of the country. There was, however, a reason for this, namely that there were two distinct types of iron-making carried on in England at that period. One was the manufacture of quality goods from a high class of malleable iron ; but there was also the casting or founding of iron for cheaper articles.

Darby was an iron-founder of this second kind, and the iron produced by his process was not really well-suited to the production of high quality goods, because of its cold-shortness, which lowered its tensile strength and ductility as compared with pig iron made by the charcoal process. It was perfectly suitable for cheap nails, pots, pans, etc., capable of being cast ; but the smiths of the period would not use it unless compelled, and if they did use it, expected more money for working it. It was not until about 1750 that the larger ironmasters and forge-masters of Worcestershire began to use iron made by Darby's process.

Sixty or more years after his discovery, the greater part of the pig iron smelted in England was still being produced with the aid of charcoal. Obviously, the limited application of Darby's iron, and the prejudice against it, would minimise its seeming importance, and prevent it from being widely noticed. Moreover, Darby, a Quaker, was of retiring and self-effacing character, so reluctant to publicize himself that he refused, as did Benjamin Huntsman at a later date, the Fellowship offered to him by the Royal Society. It was not until 1779 that Darby's iron was sufficiently trustworthy for the first iron bridge to be made from it at Coalbrookdale, and this bridge still exists. It is also claimed that the first iron tram plates were cast there.

Altogether there were five Darby's, all Quakers, who lived, worked and flourished from 1699 to 1851. An account of these interesting men, and of Coalbrookdale throughout this period, is contained in ' Dynasty of Ironfounders—The Darbys and Coalbrookdale ' by Arthur Raistrick. This is based on manuscripts previously unpublished, and is illustrated by plates in colour and tone.

Transatlantic Imports

From 1740 onwards the manufacture of iron in the British colonies of America developed considerably, and by 1750 we find the colonies, in particular, entering the British markets against Russia and Sweden. In 1750, an Act (23, George II) was passed encouraging the importation of pig iron from the British Colonies of America. The tremendous importations from Sweden were felt to be harmful to the nation's interests. The Act repealed the duties on American pig and bar iron on condition ' that from and after the 24th June, 1750, no mill or other engine for slitting or rolling of iron, or any

plating forge, to work with a tile hammer, or any furnace for making steel shall be erected, or, after such erection, continued in any of his Majesty's Colonies of America '.

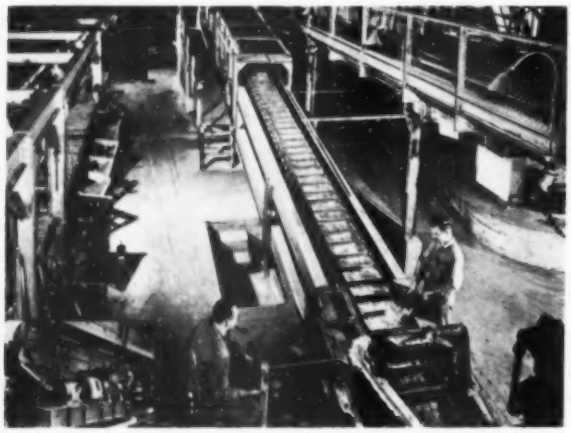
This Act aroused considerable opposition, some of it from the tanners, who feared that the woods would be neglected and they would be unable to obtain enough oak bark to allow them to follow their trade. On the other hand, the ironmongers and smiths of Birmingham thought they would get cheaper iron, and supported it. It will be seen that much hung upon the success or otherwise of Darby's process, and that it is no exaggeration to say that in a large measure British industry today owes its prosperity, and therefore an enormous debt, to Abraham Darby of Coalbrookdale.

Machine Casting Zinc Slabs

THE mechanical casting of ingots of a wide range of non-ferrous metals, including aluminium, copper, copper-base alloys and lead, has been a practical proposition for some time, and the pig casting machine is rapidly replacing the old-fashioned pig beds in the iron manufacturing field. The production of zinc slabs, however, presents a problem not hitherto solved by mechanical means. In this case it is essential that the surface of the slab shall be free from ripple and shudder marks, and of uniform quality, and the large zinc producers have previously not adopted mechanical casting, as normal drives depending on multi-sided drums or large centre link chain wheels are unable to produce the smooth transmission required. It was not until a new booster-driven machine was produced by Sheppard & Sons, Ltd., of Bridgend, Glamorgan, that satisfactory results were achieved in the mechanical casting of zinc slabs.

The principle of this new development is based on the fact that with the normal drive head of link mechanisms, chordal action occurs in some degree, and it is this chordal action which is the cause of the ripples on the surface of the slabs. The booster-driven machine, which was designed to overcome these difficulties, incorporates a drive unit mounted beneath the machine, on a separate foundation, with a caterpillar drive which engages the returning empty mould chain by a series of uniformly pitched steel dogs, so arranged and mounted on the caterpillar chain as to transit only uniform horizontal motion to the main mould chain.

The first machine of this type was supplied to the Consolidated Mining and Smelting Company of Trail, British Columbia, and is working in conjunction with the largest electric reduction furnace in the world. So successful has it been, that the interest of other large zinc producers has been aroused, with the result that further similar machines have been ordered and installed in America and Canada, and the reputation for reliability and quality of the product of these machines is becoming widely known to the important zinc producers and users.



The illustration depicts a picture of a typical machine in operation, with (inset) a reproduction of the booster driving unit. The latter comprises an electric motor driving through a thermionic valve controlled dynamatic coupling giving infinitely variable speed control to the worm reduction gear unit driving the caterpillar chain. By this means perfect control over speed is obtained without metallic connection between the driving unit and the casting machine, resulting in a product with an exceptionally smooth surface.

Industrial Cine-Magazine

FURTHER co-operation between industry and government in the interests of export promotion and British industrial prestige abroad is announced by a committee on which sit representatives of the Federation of British Industries, the Board of Trade and the Central Office of Information.

The C.O.I. is to produce a regular Industrial Cine-Magazine, in which stories about British industry will be carried to important export markets. Each issue of this film magazine will contain three or four items, and a firm or association whose product is featured will meet the cost of filming its story. In return the Government Departments concerned will pay for foreign language versions, for copies, and for distribution overseas. The main distribution will be made in the United States, Latin America, Western Germany, and the Commonwealth.

The Cine-Magazine is to be made in series-style in order to interest TV markets in U.S., Canada, and Latin America ; but it will also be suitable for cinema showings in all territories, and for specialised showings, for instance at gatherings promoted by a Company's local agent in consultation with the commercial attache of an Embassy or Legation.

David Brown U.S. Order

AN order from an American company for two hobbing machines valued at over 100,000 dollars, has been received by David Brown Machine Tools, Ltd., of Sherborne Street, Manchester. This contract, which was obtained in keen competition with German and American manufacturers, covers the supply of a large David Brown gear hobber capable of producing large gears (up to 138 in. diameter) of the exceptional accuracy normally associated with turbine gears for marine main propulsion drives, and a standard David Brown M.T. 60 gear hobber, which is a universal machine designed for cutting spur, helical, spiral and worm gears up to 60 in. diameter.

Electroplated Contacts*

By P. Quinn, B.Sc.

Works Metallurgical Department, English Electric Co., Ltd., Stafford

The choice of material for an electrical contact is governed by the conditions to be met in service, and as these are of a varied nature, a range of metals and alloys is used for this purpose. Electroplating is one of many ways of applying certain metals to provide a contact surface, and in this article the author discusses how best use can be made of an electroplating process to achieve the maximum efficiency in production and effectiveness in service.

AN electrical contact must maintain a sufficiently low resistance consistently under its designed operating conditions in the environments in which it is intended to work, and if necessary it must be capable of withstanding arcing or sparking, and resist welding.

To fulfil the first condition of low electrical resistance, in those cases where no cleaning action whatsoever is present, the surface of the contact must be kept free from oxides, tarnish films and corrosion products, and must be suitably shielded from general dirt. In other cases sufficient cleansing action is inherent in the contact duty, e.g., the third rail in traction systems.

Under some conditions contacts require very little resistance to sparking and arcing, e.g., signal-current contacts in communications equipment. On the other hand, high-power circuit-breakers require contact materials with extreme resistance to power arcs.

With so many factors to consider it is scarcely surprising to find that a large range of alloys and metals in a variety of forms is used for contact materials. Most of these materials have one feature in common, that they employ noble metals, either in the pure form or as alloys.

Once a contact design is chosen and a suitable contact material selected, the method of manufacture has to be considered. Electroplating is one of many ways of applying certain metals to provide a contact surface, and has its own particular advantages and limitations which must, in some cases, react on the design of the contact if efficient and trouble-free production is to be obtained.

These factors are discussed in detail in this article in order to show how the best use can be made of an electroplating process to achieve the maximum efficiency in production and effectiveness in service.

Mode of Failure of Contacts

(1) In the easiest conditions, the volt-ampere characteristic of the circuit in which the contact has to work is neither too high nor too low, the contact is moderately frequently operated to provide cleaning action, and the design provides adequate abrasion to remove any film from the surface (e.g., motor starters for moderate-size machinery). A base metal such as copper, nickel silver or phosphor bronze is frequently adequate as a contact material, and it is usual to make the contact from such materials and to apply no surface coating or arcing tip.

If such a contact is placed in an otherwise similar circuit, but on a duty cycle where it is required to remain closed for periods of days or weeks, it may give serious trouble on this apparently lighter duty due to tarnish or corrosion films forming at the contact face. These films increase the contact resistance, the temperature rises, oxidation becomes progressive and the position may be quickly reached where the contact is damaged by overheating.

(2) Where contacts have to remain open for long periods and handle small currents at very low voltages, the slightest tarnish film could prevent any current from flowing in the circuit when the contact is closed.

(3) On closing a highly capacitive circuit there is a large current surge which in some circumstances may approach that of a fault current. If the contact material is not sufficiently refractory, welding will take place and the contact fail to open when required.

(4) In low-current D.C. circuits, contact material is transferred from one contact to the other in operation. A spike and corresponding crater may be formed and may interlock. If the mechanical force available is not adequate to break off the spike, the contacts will not open.

(5) Contacts may be destroyed because the metal of which they are constructed is melted by the arc produced when they open. It is not necessarily sufficient to use a more refractory material; good thermal conductivity may also be required.

TABLE I.—TYPICAL APPLICATIONS OF THE PURE NOBLE METALS

Metal	Applications
Silver	Bolted high-current contacts. Current-carrying contacts on high-power circuit-breakers. Telephone and other relays. Contactor contacts. Snap and knife switch contacts. Isolators on high-current systems.
Gold	Normally-open relays for very low currents. High-frequency low-level switching.
Palladium ..	Slow-speed low-current relays, etc. Most of the applications of platinum can be carried out with palladium.
Platinum ..	Slow speed and normally-open low-current relays. Most other types of light duty contact where very little metal is required.
Rhodium ..	Signal-current contacts. Light-duty sliding contacts where considerable mechanical wear is expected.

Choice of Contact Materials

The contact material is chosen to avoid failures of the type briefly described under the previous heading. Of the large range of materials which are available, relatively few are normally electro-deposited. These are the pure noble metals and, to a lesser degree, nickel and copper. They present only a limited range of properties; in particular none of them shows the extremely high resistance to power arcs which is desirable for certain services, or exceptionally high resistance to welding.† The types of service for which they are suitable are indicated in Table I.

* Reprinted from the June 1955 issue of *The English Electric Journal*.

† It should be noted that it is sometimes necessary to separate the various requirements of a contact, e.g. an arcing contact may be used in conjunction with a separate current-carrying contact.

There is a considerable overlap of properties between the majority of noble metals, and usually the choice is partially governed by cost: the metal is selected which can be most cheaply applied and which will perform the services required. It should be noted that when the cost of the solid metal only is considered, the price per unit volume is the criterion, and not the price per unit weight. Table II gives the relative costs of the electro-deposited contact metals on both a weight and a volume basis. Silver is the obvious first choice in cases where the tarnish resistance of the base metal (usually copper) is inadequate. It has the lowest price among the noble metals and the highest electrical and thermal conductivities known. Its main disadvantage is that it forms a sulphide film, occasionally containing a little sulphate, which can interfere with the operation of light contacts.

The sulphide film on silver has been stated to be a good conductor, as it apparently allows the passage of electricity provided the circuit voltage and current are reasonably high (i.e. above 50 volts and above 1 ampere). In actual fact, its conductivity is about $0{\cdot}01\%^{1,2}$ based on the International Annealed Copper Standard (I.A.C.S.) of 1·7241 microhms/cm³ at 20° C. It is nevertheless a sufficiently good conductor to allow the passage of some current, and local heating readily breaks down the film to silver, as the sulphide is thermally unstable. A further factor which assists the maintenance of good contact is the fact that silver sulphide is relatively soft and plastic, and tends to be squeezed out from the point of contact.

Silver is readily welded under high pressure, the weldability being quite marked at room temperature—a drawback where considerable heating is to be expected. This phenomenon is sometimes referred to as "picking up" under sliding friction. As a result, the pressure density which can be applied is relatively low.

Silver has a fair resistance to bridge transfer (i.e., the transfer of metals from one contact face to another) but in light-duty contacts the spike and crater type of failure may occur. At high currents there is considerable "splash" on the transferred metal, and no spike is built up.

Palladium is little used as an electro-deposited contact material. There is no justification for this, as it would serve well in many circumstances where silver is not adequate, and it is less expensive than all the other noble metals. It is completely resistant to sulphide tarnishing, but not completely resistant to oxidation at temperatures above 350° C. Palladium is also harder and more resistant to welding and bridge transfer than silver under most conditions. Its electrical and thermal conductivities are not as good as those of silver or rhodium, but are as good as those of platinum.

Gold would appear to merit attention where only good conductivities coupled with complete freedom from surface films are required. Its electrical and thermal conductivities are next to those of silver in the noble metals, but it is very soft and has a great tendency to cold-weld. A gold "flash" has been applied to silver contacts to prevent tarnish, but its permanence in the contact area is doubtful, even for light duties. It is useful in preventing unsightly tarnish on visible but unimportant portions of less noble metal contacts and is not expensive, as one millionth of an inch is effective for several years if the operating temperature is not high. One objection to its use for this purpose is that its colour "clashes" with that of other visible components plated with near-white coloured metals.

TABLE II.—RELATIVE COST OF PRECIOUS METALS

Metal	Relative Cost (Silver = 1)	
	By weight	By volume
Gold	40·2	74·3
Iridium	185	395
Osmium	162	347
Palladium	27·6	31·4
Platinum	87·6	178
Rhodium	146	172
Silver	1	1
Copper	0·02	0·02

Rhodium is as cheap as platinum when considered on a volume basis, and is also harder and has higher conductivities. It forms no sulphide films, but does form a tenacious oxide at about 900° C., which decomposes at still higher temperatures. Rhodium has much the same mechanical properties as electro-deposited chromium. It is hard and brittle and is consequently prone to cracking, unless deposited on a reasonably hard, rigid base. Its greatest use is in signal-current circuits, where it is valued for its low "noise."

Electro-deposited platinum is only worth considering when a hard, completely tarnish and oxidation-resistant metal with a certain amount of ductility is required. Its conductivities and hardness are less than those of rhodium, and its only real superiority to palladium lies in its resistance to oxidation at high temperature, and its slightly greater hardness.

The other precious metals—osmium, iridium and ruthenium—are most costly, and have little value for electrical contacts as pure metals, as they are less stable chemically than the other noble metals. They are used in alloys which are not commercially electro-deposited.

Some mention must be made of nickel, copper and tin, which are used in the electro-deposited state for bolted contacts. All three suffer from thermal run-away if overheated, and are therefore less suitable than silver for bolted joints where current rating is important. Copper is mainly of interest as a coating for steel when a joint is required to retain good high-current earthing properties. Its use is rare, as the normal protective coatings are as satisfactory. Tin and nickel are sometimes applied to copper and its alloys to improve their tarnish resistance. The most common example of their application is the ordinary soldering tag.

Neither tin nor nickel is satisfactory for a contact surface which has to make or break current; they are considerably less reliable than copper for this purpose.

Choice of Manufacturing Process

In many cases the best production technique is obvious. For example, certain metals cannot be electro-deposited and must therefore be worked by other means. Again, the shape of the contact may be such that only electro-deposition is feasible. Between these extremes there is a range of circumstances in which there is a choice of several methods of manufacture. Sometimes technical reasons dominate the choice of method; on other occasions the decision can be based purely on relative cost. In addition to electro-deposition, a contact face may be secured to the body of a contact by riveting, brazing, soldering, spot welding, or by extruding or rolling a bi-metal section or strip.

Riveting involves weakening the contact by drilling holes, and the rivet itself may not be satisfactory, as

TABLE III.—PROPERTIES OF SOME METALS, SHOWING THE DIFFERENCES DUE TO ELECTRO-DEPOSITION

	Melting Point °C.	Electrical Conductivity %I.A.C.S.	Thermal Conductivity C.G.S. units	Annealed		Electro-deposited	
				Hardness D.P.N.	U.T.S. lb./sq.in.	Hardness D.P.N.	U.T.S. lb./sq.in.
Copper	1,083	100–102*	·94	40	32,000	60–150*	—
Gold	1,063	70–76	·70	32	18,000	60–70	—
Nickel	1,455	20–25	·20	70	46,000	150–450	80,000–250,000
Palladium	1,554	16–18	·17	37	27,500	250–300	—
Platinum	1,773	16·2	·17	37	18,000	400–500	—
Rhodium	1,966	35–37	·21	122	140,000	600–800	—
Silver	960	106	1·00	30	23,000	60–70	30,000–35,000
Hard Silver Plate	960	106	1·00	—	—	100–140	40,000–50,000

* Acid copper deposits.

the heads tend to be sheared off in some mechanisms.

Brazing and soldering are limited to simple shapes. The former is frequently undesirable, as the heating used in the process can adversely affect the mechanical properties of the base-metal contact body or the contact metal itself. Soldering is unsuitable where considerable heat is likely to be generated in service, or where mechanical strength is important. Both these processes, together with riveting, very often involve considerable expenditure of time per piece, and on this ground alone can often be replaced economically by plating.

Spot welding of contact tips is limited as to size and shape. Where suitable it is a most economic process, and plating can rarely compete on cost, though it may do so in some limited cases where the resulting local softening and deformation of the contact body or contact tip is unacceptable.

Bi-metal is an inexpensive method of production, but is limited to large-quantity production in shapes which can be rolled or extruded and subsequently sub-divided.

Electro-deposition is the least limited process with respect to the shape of the contact body. The mechanical properties of the base are not impaired, and the deposit itself may have mechanical properties which are superior to those which could be obtained by other methods of manufacture. The mechanical properties of some electro-deposited metals are compared in Table III with those of the annealed materials. The most severe limitation on electro-deposits is one of thickness. Of the metals shown in Table III, only silver, copper and nickel can be deposited readily in thicknesses of the order of 0·01 in. or more. The other metals are normally limited to deposits 0·001 in. or less in thickness. Fortunately, silver is the metal most commonly required for medium- and heavy-duty contacts, where considerable thicknesses are normally used.

Characteristics of Electroplating Processes

The most important features of a plating process which affect design are its ability or inability to deposit an even thickness of metal over a complex shape (its " throwing power ") ; the thickness of metal which can be deposited satisfactorily ; and the mechanical and physical properties of the deposit. Before discussing individual plating processes these factors need further explanation.

Throwing Power

The throwing power of plating baths is more limited than is generally realised, and varies in a complex manner under varying plating conditions. The primary distribution of metal, i.e., the distribution which would be expected from the simplest predictions based on 100% current efficiency and the plating solution resistivity, is very poor indeed.

The throwing power of a plating solution depends on the manner in which back e.m.f.'s are produced on the surface of the work ; the way in which current efficiency varies with current density ; the conductivity of the electrolyte ; and the dimensions of the plating bath. Many attempts have been made to express the throwing power of a plating bath in terms of a percentage or number, but all the quantitative expressions derived so far are liable to serious errors of interpretation, and a qualitative description such as " good," or " fair " is still the most reliable.

Throwing power must not be confused with covering power, i.e., the ability of the plating bath to deposit *some* metal all over an object. The fact that a coating can be seen in deep recesses is in itself no indication of good throw. Good covering power is, of course, essential before good throwing power can be obtained.

Limits to the Thickness of Deposit

Little theoretical information is available on precisely what limits the thickness of a metal which can be deposited before the deposit becomes rough, spongy, or otherwise unsatisfactory. With some plating solutions the smoothness of the deposit improves as plating continues, and the first limitation is cost, or change in shape of the object being plated. The thickness which can be deposited is a feature of the individual plating solution.

Plating baths which have good throwing power, but which are limited on deposit thickness, are often used where possible in preference to other solutions which give heavy deposits and have poor throw.

Physical Properties of Deposits

The physical properties of deposits can vary greatly with conditions of deposition. The hardness is usually greater than that of the annealed material, and is in some cases in excess of that normally given by cold working.

The electrical and thermal conductivities of the deposit may not be as good as those of the normal material. Care must be taken, in choosing a plating process for contact work, to ensure that high-purity deposits are produced. Bright plating baths have to be regarded with suspicion unless it is known that the brightener does not co-deposit with the metal. Brighteners are not the only source of trouble, as the chemicals normally present in the plating bath may also co-deposit in harmful quantities.

TABLE IV.—MAJOR CHARACTERISTICS OF THE INDUSTRIAL PRECIOUS-METAL PLATING BATHS

Metal	Approximate (max.) Thickness of Deposit (in.)	Throwing Power	Ease of operation	Remarks
Silver	0·05	Good	Good	Rate of deposition easily controllable but traditional bath slow. Rapid solutions available.
Palladium	0·0005	Moderate to good	Good	Rate of deposition certain but slow. Solution very stable.
Gold	0·001	Good	Good	Rate of deposition somewhat unreliable.
Rhodium	0·001	Fair	Moderate	Deposits up to 0·002 in. have been claimed under special conditions. Careful control necessary to achieve known thickness.
Platinum	0·0005	Moderate	Fair	Solution needs careful control. Rate of deposition certain if bath working properly. Process needs constant watching.

Plating Processes

The main features of the more important plating processes are given in Table IV.

Silver Plating

Silver has been electro-deposited for well over a hundred years for decorative purposes, and more is known about its deposition than that of any other noble metal. Its use for electrical contacts is comparatively recent. At one time the only type of bath available was that used in the cutlery trade. Lately, solutions have been developed which are more suited to heavy, rapid deposition, and have considerably widened the field on medium- and heavy-duty contacts; this is particularly fortunate, as silver is the most suitable metal for this class of work, where heavy deposits are often required. It is virtually the only contact metal electro-deposited for heavy electrical engineering purposes.

The silver plating baths are economical to run and easy to operate. Chemical decomposition of the solution is slow, and replenishment of the bath by dissolution of the anodes is the normal practice. Solutions have virtually an indefinite life, with reasonable care, and the author has seen a bath in satisfactory operation which was claimed to be 60 years old. The rate of deposition can be satisfactorily controlled, as the cathode efficiency is 100%.

Palladium Plating

Palladium cannot be deposited in great thicknesses, and its use is therefore limited to light duties. The modern plating solutions are easy to handle and the rate of deposition is certain. The solution cannot be replenished by anode dissolution, and the metal has to be added to the bath in the form of salts. Nevertheless, deleterious chemicals do not accumulate in the solution, as the breakdown products of the salts are water and volatile gases.

Gold Plating

Commercial gold solutions are most suited to thin decorative plating. This is of little consequence as only "flash" deposits are normally desired. The rate of deposition is somewhat uncertain, as the current efficiency of the solution is variable. Replenishment by anodic dissolution is possible, but is not normally practised, most operators preferring to add the metal as salts and replace the solution occasionally when it becomes too contaminated with decomposition products.

Rhodium Plating

Rhodium is unique in that it is used as the pure metal only in the electro-deposited state, although there are some applications for rhodium-containing alloys. It is an extremely hard and quite brittle metal, and is not suitable for normal methods of fabrication.

Careful control of rhodium plating solutions is necessary if the thickness of the deposit is to be controlled with reasonable certainty. The plating solution is stable, but anodic replenishment is not possible, and this results in a build-up of free sulphuric or phosphoric acid in the solution. The metal is added as a solution of the sulphate or phosphate. The bath is not as easy to handle as the silver, gold or palladium baths.

Platinum Plating

Platinum is not an easy metal to deposit satisfactorily. Attempts have been made to deposit it from solutions similar to those used for palladium, but these have not proved commercially successful. The bath at present used has very serious disadvantages and limited life. Slight traces of cyanides cause the deposition of metal to be inhibited almost completely, and the bath has an unhappy characteristic of suddenly changing from depositing metal at 100% efficiency to depositing little metal at all. The remedy is to turn off the current and allow the bath to stand for a time before continuing to plate. Good results can be achieved with care, but the process is naturally unpopular.

Copper, Nickel and Tin Plating

These metals can be deposited very satisfactorily from a large selection of plating solutions. They jointly account for the vast majority of all the metal which is electro-deposited in the world to-day. Apart from the somewhat limited throwing power of the nickel plating baths at present in commercial use, there is no particular limitation on any of the processes. It is worth noting that copper and nickel may be deposited with a range of mechanical properties, and in thicknesses up to 0·25 in., if suitable control is exercised, and these metals find limited use in electro-forming contacts with internal precious-metal facings. The procedure is to deposit the desired surfacing metal on the male forming pattern and to follow this by a heavy deposit, usually of copper, after which the pattern is extracted. This method is particularly suitable for the manufacture of wave-guides.

Design Features

Plating should be considered as early as possible in the design of a contact, particularly where heavy deposits are likely to be required. If this is not done, and plating is added as an afterthought, the results may be disappointing or the requirements impossible to fulfil.

Shape of a Contact

For the best and most economic results, the contact area should be an external convex surface, with no sharp edges or corners. This is an ideal, but it can be approached quite often. Such a contact will acquire the thickest deposit on its working surface, and the deposit can be confined to the contact surface without special anode arrangements if the deposit is a heavy one. If a female contact is used it should, where possible, be made up of a number of elements which can be treated

TABLE V.—USEFUL BINARY CONTACT ALLOYS WHICH HAVE BEEN ELECTRO-DEPOSITED
(After Faust,[3] with additions since 1940)

	Cobalt	Copper	Gold	Iridium	Lead	Molybdenum	Nickle	Palladium	Platinum	Silver	Rhodium	Tungsten
Cadium			X							X		
Cobalt							X			X		X
Copper			X				X	X	X	X		
Gold							X		X	X		
Iridium								X	X	X	X	
Lead										X		
Molybdenum												
Nickel										X		X
Paliadium									X	X	X	
Platinum										X	X	
Silver											X	
Rhodium												

individually. Large parts which require plating on small areas only are best avoided, as they reduce the output of the plant and increase the amount of labour expended on " stopping off " the unplated area.

The shape of a contact may be such that it cannot be jigged or wired easily (e.g., a sphere). In such cases poor electrical contact with the suspender in the plating bath may result in thin deposits, or the contacts may fall off the suspension during treatment. This may result in the destruction of the contact, as it may be too badly attacked by acids or other chemicals to be of further value.

Solution Traps

Certain methods of jointing such as riveting and spot welding invariably lead to trapping of solutions in the joint. This can cause trouble with contaminated plating solutions and subsequent seepage and corrosion of the contact after it has left the plating shop. Similarly, braded or laminated flexibles should not be attached to an assembly before plating.

A problem sometimes arises with tubes which require plating externally. The inside of the tubes may not be covered completely with the deposit, and attack by the plating solution is usual in such cases. This may not seriously injure the component, but if repeated frequently it is almost certain to cause trouble with the plating solution ; the resultant cost may be hundreds of pounds. This difficulty is easily avoided by sealing the ends of the tubes with a soldered or brazed plug. Bunging the ends with corks in the plating shop is not a satisfactory answer, as they may blow out on entering a hot solution, or a cold solution may be drawn in slowly by changes in air pressure inside the tube.

Base Metals

The base metals used for contacts are almost invariably copper alloys. Most of these are easy to plate, but beryllium copper and some of the high-tensile brasses (manganese bronzes) may cause difficulty, as they are not always recognised by the plater and require slight variation from the usual treatments. Occasionally a contact is made from an aluminium alloy, and in such cases it is most desirable that the silicon and, particularly, magnesium contents should be as low as possible. Some high-magnesium alloys are almost impossible to plate satisfactorily.

The contact should be as homogeneous as possible. The use of even two copper alloys in the same assembly can seriously reduce the chance of a completely satisfactory job, while some combinations are virtually unplatable. Difficulties of this type are fortunately rare.

Planning

Usually an article is plated after it is otherwise completed. When a protective or decorative deposit is to be applied this is in most cases correct, but when an engineering deposit is required it is sometimes the worst and often not the best procedure. It is impossible to generalise sufficiently to cover a substantial proportion of cases, and consultation with the plater is the best approach to this problem.

A frequent cause of trouble is the incomplete removal of mill scale, brazing and welding fluxes, or foundry sand from articles before they are machined. The plater is then forced to use long pickling times in strong acids (or even shot-blasting) in order to obtain an adequately clean surface on which to plate. The effect on dimensional tolerances can be most unsatisfactory. This matter should never be left to chance, but heavy cleaning should be planned as a separate operation after welding and brazing, before final machining.

A production batch should, if possible, be adequate to form at least one load for the plating bath. Plating part or mixed bath loads leads to very poor productivity and doubtful thicknesses.

Future Developments

Electroplating is likely to remain much more of an art than a science for some years to come. The scientific development in this field has made considerable headway in the last two decades and is continuing at an increasing pace ; much of this work has resulted in laboratory processes which could be further developed and used for production if an adequate demand existed.

One of the perennial problems of the electroplater is

that of producing local deposits limited to a defined area. One approach to this is the traditional " stopping-off " procedure. More recently, attention has turned to the old plater's practice of " doctoring " local areas of a deposit by applying an anode wrapped in a rag soaked in plating solution. A successful process of this type (brush plating) has been developed for depositing thin films of silver on busbar joints and other bolted connections ; it has now been in large-scale use for several years and is a technical and economic success. Several processes of the same type have been on the market from time to time, but all have had severe economic disadvantages, and deposit thicknesses have been limited.

Alloy plating has been gaining ground industrially for some years. It has not yet found favour for electrical contacts, because no adequate demand exists for any of the alloy plating baths which might be useful for contacts. Table V illustrates the extent of the laboratory work carried out, and some of these processes are successful for commercial decorative plating. The work of Brenner[4] on alloys of nickel and cobalt with tungsten is of special interest, as it offers the possibility of electrodepositing arcing contacts. His nickel-tungsten process produces alloy containing up to 40% tungsten, and is not difficult to operate in the laboratory. The main objection to it is the amount of ammonia fume evolved.

A method of depositing gold alloyed with nickel, copper and silver, recently described by Gardam[5], enables the proportion of the metals in the alloy to be varied by turning a knob. The principle of the method is suitable for commercial exploitation.

Tertiary alloys have not been neglected, and silver-platinum-gold, silver-platinum-palladium and silver-platinum-copper have been deposited in the laboratory.[6] The object of the investigation was to produce a low-cost alloy identical in appearance with silver but completely resistant to tarnishing. The processes are not suitable for commercial development, but the investigation considerably narrowed the range of possible solutions by eliminating a large number of impossible approaches.

Electroplating has conventionally been carried out using smooth D.C. or raw rectified A.C. Recently, unsymmetrical A.C. has been coming into use for this purpose. It has attracted much attention and has been shown to have many advantages. The inclusion of this " partial reverse (P.R.) current " plating as a " future " development is justified only by the fact that it is certainly in its infancy, and is not yet entirely satisfactory for general use.

Acknowledgments

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Aluminium Motor Cruiser

THE *Pearl Diver*, a 34 ft. aluminium alloy motor cruiser has recently been completed by the Itchenor Shipyard, Ltd., for Mr. N. E. Carter of Bognor Regis. As the illustration shows, she has an attractive and orthodox appearance and her performance has fully justified the hopes of her owner and builders. The *Pearl Diver* has a beam of 9 ft. 4 in. and a draught of 2 ft. 3 in. and the shell thickness is 12 s.w.g. Of particular interest is her construction, which is of riveted aluminium alloy using the " two-way tension " system pioneered by Universal Launches, Ltd., of Bideford ; the craft has been built under licence to this company. The alloy used for sheet and extrusions was BA.27 (NS5 and NE5) supplied by The British Aluminium Co., Ltd.

Accommodation consists of a double berth fore cabin ; toilet and washbasin compartment ; saloon containing two settee-berths ; galley aft. A 7 ft. 6 in. dinghy is carried in davits at the transom. Decorative trim is in mahogany and the interior is comfortable and well lit : a Pye-Dolphin radio telephone is fitted for ship to shore communication. The engines are two Austin Skipper 60 petrol units, each developing 60 b.h.p. at 3,200 r.p.m., and these give a comfortable cruising speed of 14 knots with a maximum of around 18 knots. No reduction gears are fitted ; fuel capacity is 80 gallons. The resulting yacht is a handsome and comfortable cruiser easily handled. She was designed with a view to long life, and the minimum of maintenance charges for her owner.

Resistance Welding Demonstration Facilities

To extend facilities for developing resistance welding techniques and investigating specific production problems, Philips Electrical, Ltd., have recently installed at their Brixton (London) applications centre, a special multi-purpose machine including both seam, spot and projection heads. The seam welding head—which is identical to that in the company's E.S.2003 series plant—can be used for either circumferential or longitudinal work. The machine, which has a nominal rating of 100 kVA., is electronically controlled by a Philips Tempomat, thus providing for the development of sequences involving phase-shift heat control, slope control and multi-pulse welding. Visitors to the centre can also inspect the full range of Philips pedal and air-operated spot welders, welding gun, portable equipment, etc.

Modern Concepts in the Protection of Magnesium Base Alloys*

By W. F. Higgins, M. Sc., Ph. D., A.R.I.C.

Senior Metallurgist, Magnesium Elektron, Ltd.

Although magnesium alloys are frequently used in the unprotected condition, improved composite schemes have been devised to ensure that the maximum protection is secured where particularly corrosive environments are likely to be encountered. In discussing such a scheme, the author pays particular attention to the purification and passivation of the metal surface, and to the subsequent sealing by means of an organic resin prior to painting.

THE extended use of magnesium alloys in recent years and the widening range of service conditions involved have had interesting repercussions on the question of surface protection. On the one hand, it has been shown beyond doubt that magnesium, like the other engineering metals, steel and aluminium, zinc and copper, tin and lead, may frequently be used in the completely unprotected condition. To those, and they are many, who think of magnesium in terms of flash powder and incendiary bombs, this may be a novel concept, but it is too well attested in such applications as the Ferguson tractor transmission case, the various Volkswagen components, and the warp beam flanges, bobbins and pirns of the textile industry (to mention only a few) to be gainsaid. On the other hand, the freedom which such inspiring applications has revealed has brought new problems with it, for the advanced designer now tends to move too rapidly in the opposite direction, and frequently proposes the use of magnesium alloys in conditions which might well give pause for consideration. The consequence of this is that the older simple protective schemes which were, and still are, adequate for many purposes, have had to be supplemented by improved processes in order to keep pace with the visions of designers, if not with the immediate needs of industry. It is the purpose of this paper to indicate the directions in which improved protection is being achieved, and to outline the processes which are adding to the versatility of the magnesium rich alloys.

From the early days, the need for foundation treatments was recognised, and the passivating effect of the chromate ion has been exploited in many different treatment baths. Despite a very extensive search by Whitby and others, nothing quite as good as chromium has been found, but the films produced in these baths are all, without exception, too thin to offer much resistance to physical damage. As a consequence, there has been a tendency to seek a treatment which gives thicker and harder films, even if this means sacrificing the inhibiting properties of the chromium compound. No success has attended efforts to form thicker and harder films merely by chemical means, and the heavier films now being produced are the result of interaction with nascent ions produced in electrolytic baths. Under such conditions, it does not seem possible to include the chromate ion in the form in which it is required for passivation. Since, however, the films are porous to some degree, or at least capable of absorbing liquids, there seems no reason why soluble chromates should not be absorbed into such films as a subsequent step. It is, indeed, usual to seal the films with organic materials—waxes, lacquers and the like—in order to prevent ingress of all aqueous corrodants, and an inhibitor pre-absorbed into the film would seem an obvious step to take. Among treatments depending on electrolysis of various solutions which have recently been announced in the U.S.A., are the " H.A.E." process emanating from Frankfort Arsenal, the " No.17 " process developed by the Dow Chemical Company, and the still more recent " CR–22 ", also from Frankfort Arsenal. Both the latter yield films which are green in colour, probably indicating the presence of chromium compounds (which are certainly present in the Dow bath), but in a form in which they are probably not capable of exerting a passivating action. The H.A.E. process, when carried out to completion, yields a dark brown or chocolate colour, but modifications, which are essentially short period treatments, give lighter coloured and, incidentally, thinner films. The full H.A.E. film is extremely hard, but it is brittle and spalls badly under shock. It also has a considerable adverse effect on the fatigue resistance of the metal.

How far any of the above treatments are necessary depends entirely on the environment in which the component is to be used. Corrosion or rusting is the result of interaction of a metal with its surroundings, and no metal corrodes unless the substances in contact with it are sufficiently active to cause attack. It is the atmosphere, not the metal, which is corrosive. The need for protection against the surroundings in all delicate structures where corrosion is of importance, and where its incidence may lead to inefficient or unsatisfactory performance, is illustrated by the fact that all such structures are assembled and built indoors. No intelligent watch-maker would work out of doors on the sea shore. Right from the start some attempt is made to keep the weather at bay. Sometimes very great efforts are made to exclude the weather, and air conditioned and dust-free rooms are provided for the assembly of the more delicate mechanisms. It is true that this step is usually taken to reduce the fouling effect of dust on bearings, etc., rather than actual corrosion of the metal parts, but the two factors are so closely related that the same practice serves both requirements. The deposition of dust is in fact a very important contributory factor in many examples of corrosion.

The principle of protecting structures during the building period is, or should be, merely the prelude to protecting them during service, and the fact that

* Paper presented at the international meeting of licensees of Magnesium Elektron, Ltd., held on June 16th-17th, 1955, to mark the coming-of-age of the company.

different methods have to be adopted at different stages only shows that the one is an extension of the other. A motor car is built indoors and the roof of the factory protects it from rain and foul weather ; it cannot carry the factory roof with it when it goes into service, but it can and does carry a full paint system, and often a layer of wax. Maintenance of the latter is just as much a part of good practice in corrosion prevention as maintence of the factory roof.

Surface Condition

Turning to the special problem of painting magnesium, a consideration of the difficulties involved may be used as a basis for devising a composite scheme embracing suitable foundation treatments with adequate painting measures. Leaving aside the obvious requirements of grease- and dirt-free surfaces, there remains the problem of knowing just what the surface really is. It is well known that the adhesion of paint varies greatly with the humidity conditions obtaining when it is applied, and air conditioning is becoming more and more popular in the paint industry as a means of ensuring uniformity of results. In the case of metals, even in normally dry conditions, there is the phenomenon of adsorption and occlusion of gases and vapours to be reckoned with. It is commonly believed that the true surface of a metal is covered with a dense layer, possibly many molecules thick, of water vapour, and of the acid gases present in industrial atmospheres which the latter may absorb. Such adsorbed layers are very difficult to remove. It follows, then, that the question of the adhesion of paint is really that of adhesion to an adsorbed film rather than to true metal. Any treatment which tends to displace or remove such a film, and which in effect brings the paint closer to the metal, will almost certainly react favourably on adhesion. In the case of magnesium, there is the complicating factor that reaction with the moisture of the atmosphere produces a layer of magnesium hydroxide, possibly of molecular dimensions only, but sufficiently soluble in the atmospheric moisture to give a definite alkaline reaction. This fact too has considerable bearing on the type of paint which can be used with success. Those paints which are sensitive to alkalies, especially the older oil-bound type, are liable to become brittle after an unduly short period of service.

Another factor which is often not fully realised is the very imperfect condition of the surfaces of most castings. The typical matt surface of a sand cast skin may commend itself as having a certain amount of mechanical " key " which should encourage the adhesion of paint. This indeed is true, but if a section of such a surface is examined under a microscope, it may be found that, in addition to its natural roughness, there are many tiny faults and flaws causing cavities over which the paint skin normally forms a bridge. This in itself is possibly of no great harm, since the same must be equally true of other cast metals, but in the case of magnesium, moisture attracted into flaws by capillary action, and later reacting, may produce corrosion products which burst through or lift off the paint. It is significant that, particularly in humid conditions and especially during storage, the slight corrosion which normally erupts through the paint on castings occurs chiefly on the unmachined areas where such surface defects as have been described are most frequently found.

Composite Scheme

Having considered some aspects of the problem, it is now possible to detail the steps in the composite scheme which it is considered should be applied if the maximum protection of magnesium alloys is to be secured, and to show how the application of a few simple principles can overcome most of the difficulties. It should be emphasised that the procedure outlined below is intended for the more searching applications only, but, since it is basically sound, the individual operator will decide for himself how far it must be followed or relaxed in any given case.

The various features of the composite scheme are as follows :

(1) Correct design of the components.
(2) Surface purification and passivation.
(3) Surface sealing.
(4) Final assembly and painting.

It will be realised that these four steps constitute nothing but a logical sequence, and the only two which are even in any way new are surface purification and sealing, which will be considered in rather more detail in the following sections.

Design Factors

Attention to the design of a component may often make the difference between success and failure. For instance, no paint film or coating system can give protection on sharp edges and corners, especially when these occur in the form of burrs. The moral is to avoid burrs and provide generous radii wherever possible. Furthermore, paint which may be quite satisfactory when used to prevent ingress of casual moisture may break down completely when it is expected to do duty as the lining of a water-filled bowl, so that contours should be chosen so that hollows capable of filling with water are not present.

Surface Purification and Passivation

Surface purification and passivation is simply a means of putting the magnesium into its best condition to resist corrosion. It assumes that any given sample of an alloy has a certain intrinsic ability to withstand corrosion and that this ability is, in practice, seldom, if ever, realised to the full for various reasons connected with production requirements. As made, a casting is usually contaminated with moulding sand or mould dressing. If it is " cleaned " by shot or grit blasting, contamination with cathodic material in the form of iron particles usually results, and this decreases its corrosion resistance very considerably indeed. If it is pickled in acid baths, the chances are that cathodic metals already in solution may be redeposited and lead to increased corrosion tendencies. Working from such considerations, M.E.L. have developed a purifying method—fluoride anodising*—which involves anodising the magnesium in a solution of ammonium bi-fluoride, with the result that all cathodic metals initially present or picked up during factory operations are removed as soluble compounds. Foundry sand, oxide skins and flux inclusions (if present), as well as iron contamination from shot blasting or machining, are also removed, and the result is that the surface of the casting is left free of all corrosion-promoting contaminants. In other words, the casting has been brought to the maximum intrinsic resistance of which it is capable. Additionally, it becomes coated with a thin, adherent film of magnesium fluoride. This may be left *in situ* and will serve as an adequate foundation for sealing or, if desired, it may be removed quite simply and a chro-

* British Patent No. 721,445 and Patents pending abroad.

mate film substituted by immersion in the usual chromating baths.

Surface Sealing

The question of surface sealing is, perhaps, the most important step of all. Surface sealing is a special step, quite distinct from painting, and one which, while it may in many cases take the place of painting, will usually be followed by a normal paint scheme. Reference was made earlier to adsorbed films of moisture, and to surface flaws which can absorb and retain liquid, leading later to paint breakdown. The M.E.L. sealing procedure is designed to overcome both these problems. The casting as soon as possible after fluoride anodising (and, if desired, chromate treatment) is heated to 200° C. This effectively dries off the surface and, furthermore, drives the moisture out of surface flaws. The casting is then cooled, but while still fairly hot, say 60° C., is dipped into " Araldite " 985E surface coating resin.† By this means, a quenching effect is obtained which helps to draw the resin solution into the flaws. After a sufficient period of time to allow the solvent to evaporate, the casting is stoved at 200° C., and the process of cooling, dipping and stoving repeated until three coats have been applied. Three such coats suitably applied, together total less than one thousandth of an inch in thickness, with a weight increase of rather less than 1½ oz./sq. yd.

The special virtue of Araldite 985E is that the resin passes through a very labile phase just prior to polymerisation, and it is this labile condition which enables it to permeate so thoroughly into the flaws and cavities. Unless preheating to the full temperature of final stoving is performed, however, there is a risk of aqueous vapour from the flaws blowing out through the resin while it is being stoved, thus causing pin holes which do not subsequently close. Thus the requirement of adequate preheating is a very important one, and failure in this respect is probably the reason why Araldite has in some quarters received the reputation, quite undeservedly, of being prone to pin-holing. The method of application is just as important as a proper choice of sealant.

Apart from this characteristic, Araldite 985E, when fully stoved, is a tough, water-resistant resin with extremely strong adhesion to magnesium surfaces. This latter property, as well as its flexibility, is attributed to its special configuration of hydroxyl groups. These are the polar groups which are usually regarded as necessary in a large organic molecule for securing good adhesion to metal surfaces. Without polar groups of this type, poor adhesion usually results, as, for example, in the case of polythene. If too many such groups occur, or if they occur too closely together, the coating may develop brittle characteristics. In the case of Araldite 985E, the groups appear to be just about right for optimum attachment to magnesium surfaces, but they are not necessarily brought fully into play without the interaction of heat. It is not expected that cold-cured resins will ever be found having quite the same characteristics as those in which heat is used to attach them to the metal surface.

Together with its waterproof qualities, the good adhesion of Araldite is of the greatest importance since it very greatly limits the tendency of corrosion to spread from any small point of damage that may occur. Despite its glossy surface, it makes a very good base for painting.

† Aero Research Ltd., Duxford, Cambridge, England.

It has hitherto been considered good practice to apply a first coat of a zinc chromate primer to magnesium alloys. The theory is that moisture which may pass through a normal paint film (which is always permeable to some degree) leaches out a little chromate and the metal below is thus encouraged to remain passive. Now it is little use including zinc chromate in Araldite surface coating resins, as the lacquer is so very waterproof that the chromate is too well locked up to be leached out effectively. On the other hand, since one of the functions of zinc chromate is to provide a supply of chromate for passivating surface abrasions (and damaged areas inevitably occur on painted surfaces), there is a good argument for applying it on *top* of the Araldite, that is, as a primer for a normal paint scheme in the usual way, but applied over the sealed surface.

Assembly Factors

Assembly, like design, is one which is not usually covered by a protective scheme as such, and yet is of the greatest importance, for it can make or mar the result. Broadly it entails sealing gaps or interstices which otherwise attract and hold water ; it means the use of sealing compounds to convert stepped surfaces into neat fillets—a device which is so old that it is believed to have been used in the pyramids ; and it means the use of tapes and insulating washers and sealing compounds, to insulate or space apart diverse metals, and so reduce the possibility of conditions arising where bi-metallic couples can become active.

General Considerations

All these points are really very obvious and logical. It has sometimes been said that they entail a great deal of extra trouble, and one detects a tendency sometimes to omit them, but if conditions are really corrosive, then those conditions must be kept at bay. The scheme outlined is a means of doing this, but all the parts are related to each other and form a consistent whole : each should be considered in relation to the rest and, in particular, to the nature of the application itself. It is little use carrying out the surface sealing procedure if the design is initially bad, or if unsatisfactory methods of assembly are used. On the other hand, where conditions are light, where magnesium parts are freely aired and not exposed to high humidities or salt water spray, little in the way of protection may be required.

Corrosion is a matter of degree, and a very sharp distinction should be made between progressive corrosion resulting from the continued subjection of a component to deleterious conditions, and that type of superficial corrosion or " rusting " to which magnesium alloys (like mild steel and cast iron) are subject. The first will inevitably lead in a shorter or longer time to disintegration of the component, or at least to reduction of its strength to a dangerously low level, while the second, though it may spoil the appearance and is generally unsightly, will have little or no effect on the structural strength. In considering a possible application for magnesium alloys, the degree of superficial deterioration which can be tolerated is worth bearing in mind. This is done in the case of mild steel. Farm equipment usually lies out in the weather and becomes gloriously rusty, but no one says it has " corroded " or thinks the worse of it. Magnesium components behave in much the same way—though to a rather less degree—as may be seen by

anyone who cares to walk round our stock of scrap magnesium alloy materials stored in the open. The deterioration is entirely superficial and no question of intercrystalline corrosion arises. The metal is just as corroded as it appears to the naked eye—no more and no less—and, if removed indoors into good dry storage, the effect is completely arrested and the metal will remain indefinitely without further deterioration.

Quantity Production of Tractor Castings in Elektron*

By W. J. Sully

Director and General Manager, Sterling Metals, Ltd.

During the past eight years more than 450,000 magnesium castings have gone into service all over the world as the backbone of the Ferguson tractor, and have proved entirely satisfactory under the arduous operating conditions encountered. The author discusses the development and production of these castings in Elektron Commercial alloy.

SHORTLY after the cessation of hostilities, in 1945, Mr. Harry Ferguson made arrangements with the Standard Motor Company, of Coventry, to manufacture his Ferguson tractor in bulk in this country. He is, it will be remembered, a great believer in a light-weight vehicle which will not pack heavy soils, and the final design of his tractor was greatly influenced by this desire for a really light-weight job. Mr. Edward Player, Managing Director of Birmid Industries, was asked to advise on the choice of materials for castings, and he made the bold suggestion that the transmission case which is really the backbone of the tractor, should be made as an Elektron magnesium casting.

The initial designs had postulated cast iron for the transmission case which, in that metal, weighed 165 lb., but in 1946, when the project was under review, there was no spare iron-founding capacity for a casting of this size, in the quantities envisaged. Sterling Metals' technicians, combining in consultation with those of the Standard Motor Company, redesigned the transmission case completely, and eventually produced a design which, when translated into a casting in magnesium, weighed only 53 lb. (a saving in weight as against cast iron of 112 lb.), and which, on arduous rig tests, proved to be stronger than the cast iron transmission case. The alloy selected was the normal Elektron Commercial alloy, known in England as 'C' alloy (not to be confused with Dow 'C' alloy) with composition and mechanical properties as shown in Tables I and II.

TABLE I—TYPICAL COMPOSITION OF ELEKTRON MAGNESIUM 'C' ALLOY

	%
Aluminium	8·0
Zinc	0·75
Manganese	0·20
Copper	0·10
Iron	0·01
Silicon	0·06
Nickel	0·01
Magnesium	remainder

TABLE II—TYPICAL MECHANICAL PROPERTIES OF ELEKTRON MAGNESIUM 'C' ALLOY

	SAND CAST		CHILL CAST	
	As Cast	Solution Heat Treated	As Cast	Solution Heat Treated
0·1% Proof Stress (tons/sq. in.)	4–5	4–5	4–5	4–5
U.T.S. (tons/sq. in.)	8–10	13–15	10–12	14–16
Elongation (% on 2 in.)	1–3	5–8	2–4	8–12

Preliminary Tests

Concurrently with the rig tests on the prototype castings at the tractor plant, an intensive series of 1,000-hour tests was carried out by Sterling Metals' laboratory to determine the possible corrosive effect on the tractor castings of the numerous types of agricultural chemicals and fertilisers which might come into contact with the transmission case during service. Some of these tests were carried out on specimens of bare metal and with intermittent water spray, to simulate field conditions of weather and of rough usage, namely paint and primer scratched off by the farm workers' boots and other forms of damage to any applied coatings. Further tests were also carried out with animal manures.

From the foregoing, it will be understood that all the circumstances which could conceivably be found detrimental in field service were, as far as possible, considered, and appropriate tests made. The magnesium transmission case withstood all these tests satisfactorily.

Here, brief reference may be made to the remarkably good behaviour of the 'C' alloy specimens at the Birmid Marine Exposure Station at Beaumaris, Anglesey. At this station, hundreds of metallic specimens, in a variety of alloys, both magnesium-base and aluminium-base, are under test, and it is notable that, after six years exposure in sea air the 'C' alloy, with all its impurities, is standing up as well even as the best of the aluminium alloys.

Having satisfied the Ferguson Organisation on these matters, arrangements for bulk manufacture were put in hand at the foundries and production commenced in April, 1947, and has been continuous from that time onwards. Initially, the work was shared between two Birmid Companies—Sterling Metals and the Birmingham Aluminium Casting Company—but later it was decided to concentrate all this production in one foundry, and from that time onwards Sterling Metals have handled the work at their Nuneaton plant.

Production Problems

The production problem was not an easy one, because it was necessary to sell the tractor castings at a price much lower than had ever previously been envisaged for Elektron magnesium castings, and today's selling price is

* Paper presented at the international meeting of licensees of Magnesium Elektron, Ltd., held on June 16th–17th, 1955, to mark the coming-of-age of the company.

more than competitive with current aluminium prices. Therefore, amongst other things, maximum economy of raw materials was postulated, and to this end it was decided that cores should be produced in exactly the same sand mix as the moulding sand, so that, at the shakeout, the whole of the mould and core sand could be conveyed back into the sand mixing plant and re-issued to both moulding and core shops for re-use. This arrangement has worked very well ; it is normally only necessary to add 5% of new sand into the final mix, and a minimum of sand is discarded—only sufficient in fact to avoid excessive build-up of ' fines '.

The composition of the sand mix is as follows :

Base	Clean, washed and graded silica sand of 60 AFA grade
Binder	Wyoming Bentonite—2%, with 2% English China Clay (the latter for economy of dollars)
Inhibitors	Sulphur—4–5% Boric Acid—0·25%

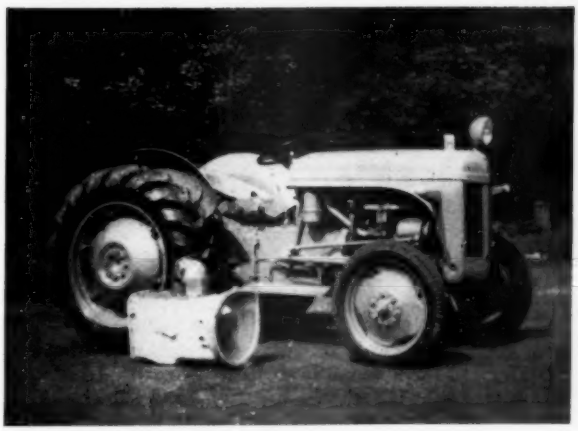
The ratio of cast weight to finished weight was, of course, all important in the interests of metal economy, and after initial technique development a poured weight of 110 lb. was established, against a fettled weight of 53 lb., that is to say, almost a 2 : 1 ratio, which was considered to be as low as practicable for a high-quality casting. In this connection, it must be remembered that, since these casings are fairly heavily stressed in service, good metallurgical quality is essential. It will also be remembered that with the Ferguson system of implements, the loading imposes a considerable bending moment upon the transmission case, which, as stated earlier, is the backbone of the tractor.

After a pre-production run, in order fully to assess the operational times by actual shop practice, keen piecework prices were fixed for all manual operations, and semi-skilled and unskilled grades of labour used, with a keen eye also on a minimum labour force. At the present 129 persons are employed on the production of transmission casings including all operations up to final despatch. Current schedule calls for a delivery of 2,000 castings per week. A five-an-a-half day week is worked and output per full day's shift is 400 castings. Output per man hour averages, in terms of weight, 12·1 lb. of castings, taking *all* operatives—foundry, coreshop, dressing shops, inspection, heat treatment, despatch and transport.

Moulding Operations

The reconditioned sand, with 5% new sand addition, is conveyor fed through hoppers to moulding machines, and to coreblowers for top half cores and rollover machines for bottom half cores, the latter cores being heavily reinforced with steel grids, since the intermediate gearbox wall of the casting almost cuts the core in two in the centre. After spraying-up, cores on magnesium core-plates are passed through a 5-loop continuous chain drying stove and, on removal, are inspected and passed along the conveyor to the core-up station.

Moulds, both cope and drag, are produced on hopper-fed jolt squeeze machines set over a gridded floor for spilled sand recovery : here it is interesting to note that the moulding boxes and the bottom mould plates are magnesium castings which, in my opinion, are better for this purpose than any other material, both in ease of handling and in long life under hard usage—all this combined with the requisite rigidity under the squeeze pressure of the machines. Feeder head cavities are formed in the cope by means of dummies fixed on the moulding machine squeeze head.



Ferguson tractor with transmission case and lower housing cast in magnesium alloy.

Cope and drag parts are removed from the machines by pneumatic hoist and runway and deposited on a roller conveyor track for finishing operations, which include skin drying under gas heater rigs. Drags are then transferred to a power driven mould conveyor.

Arrived at the coring-up station, the bottom half core is placed in the drag by two men and the top half core similarly placed on, matched up and gauged. One or two small cores are set in, the cope is closed by overhead crane and the moulds are passed by means of a power conveyor to the melting and casting shop, which is separated from the moulding shop by a complete partition, the ventilation system being so arranged that there is always an in-draught from the foundry and, therefore, no back spillage of fume from the casting shop enters the foundry.

Melting and Casting

Melting is carried out in oil-fired crucible furnaces, each crucible having a capacity of 600 lb. of magnesium : the crucibles are of one-piece deep drawn steel plate. Ladle removal from the furnace, and also pouring, is achieved by the use of two floor-type traversing jib cranes, the pouring crane having a forward speed synchronised with the mould conveyor and also a fast traverse forward and backward for quick transit of the ladle to the spot where pouring commences. Pouring takes an average of twenty three seconds, each ladle casting five transmission cases.

After pouring, the moulds pass through a 40 ft. telescopic extension of the fume exhaust and cooling tunnel, this extension being retractable and linked to the pouring crane chassis which, like a snail, carries its house on its back.

It is interesting to note here that the only materials which have been found to stand up satisfactorily under the very arduous conditions existing in the retractable portion of this cooling tunnel are magnesium castings as framework with Birmabright (aluminium—3% magnesium) sheet cladding. Fume tunnels constructed in this manner have already been in service for some eight years without excessive corrosion of the materials, and are in good working condition today. A tunnel constructed of conventional materials—steel angles and steel sheet, would last about twelve months under these conditions.

After a total period of twenty-five minutes cooling and exhaust, the castings are removed from the moulds on a vibratory shakeout and transferred (with cores *in situ*) to a slat conveyor for transportation to a specially designed vibratory de-coring rig, which effectually removes all cores, grids and chills in some fifteen seconds. The castings are then stacked to cool

Finishing Procedure

After a preliminary rough inspection, dressing operations commence by the removal of the runner system on a vertical bandsaw, after which the castings are passed through a double-head circular saw machine which simultaneously removes end feeders and flash from both ends of the casting, this operation occupying 1¾ mins. A second and smaller double-head circular saw machine, with provision for altering the height of the cutting plane, is used for removing the feeder heads at different levels on the top face of the casting, which is then passed through normal dressing operations of chipping by means of pneumatic hammer, filing, scruffing and finishing operations, when it is ready for shotblasting, heat treatment and chromating.

These various operations do not call for any particular comment, and, after chromating, the castings are jigged, location pads adjusted where necessary, finally inspected and passed through to the despatch stores.

After receipt at the Standard Motor Company's works, castings are first cleaned and degreased and dipped in zinc chromate primer, and then passed through to machining operations. Ease of handling the light magnesium transmission casings reduced machine shop costs (magnesium 53 lb. as against cast iron 165 lb.), and also reduced capital expenditure in hoisting and conveying equipment. Ease and speed of machining also resulted in considerable economies in the cycle of operations in the machine shop and, again, light weight is an advantage in handling in the assembly shop.

Operating Experience

After some eight years of production, a total of about 10,850 long tons of magnesium Commercial alloy have been despatched from the foundry in the form of tractor castings, including over 450,000 transmission cases. Of this total, customer's returns (i.e., rejects from the customer's machine shops) have averaged, cumulatively, 1·13% only. This speaks well for the inherent soundness of magnesium castings.

One other magnesium casting also forms a part of the Ferguson tractor, namely the lower steering box housing. This is produced as a gravity die casting and weighs 8 lb. 2 oz. Production of this item in the die foundry has similarly been tailored for strictest economy in metal and labour: the cast weight is 14½ lb.

It is well known that the Ferguson tractor manufactured in England has been, and is, exported to countries all over the world, and these tractors are therefore working in every climate and often under quite adverse climatic conditions. Nevertheless, after all this time, we have yet to hear of any complaints from users of corrosion, breakdowns in service, or other failures, and the spares requirements have, in consequence, been practically nil.

This long and successful run in bulk production of a tractor casing with nearly half-a-million successfully out in service in every part of the globe does demonstrate the fact that magnesium, in the form of the ordinary Commercial alloy can, and does, function satisfactorily on equipment which is usually ill maintained and often working under very adverse conditions, and at times undoubtedly subjected to extreme stresses not allowed for by the designer. It is felt that this application may therefore have helped to advance the cause of magnesium in the commercial field, and that it may in future lead others to embark boldly on new projects of a novel nature with added confidence.

Acknowledgments

This short paper would obviously be incomplete without paying tribute to the great assistance received from Major C. J. P. Ball and the staff of Magnesium Elektron Ltd., in regard to the provision of adequate supplies of Commercial magnesium metal of good and consistent quality and at an economic price. Finally, I would like to thank Mr. Edward Player, Managing Director of Sterling Metals Ltd., and the initiator of the whole project (as I have mentioned earlier) for his kind permission to present this paper, and to acknowledge the assistance of several of my colleagues in its preparation.

Correction

We regret that in the reference to M.E.L.'s coming-of-age celebrations on page 73 of the August issue the caption to the photograph of the tractor referred to it as a Fordson when it was, in fact, a Ferguson. The Ferguson is made by the Standard Motor Co., Ltd., and marketed by Massey-Harris-Ferguson (Sales), Ltd. In addition to its use on the land, the Ferguson is now being successfully applied to internal transport in assembly factories and foundries.

Industrial X-Ray Contracts

Both the English Steel Corporation, Ltd., and the United Steel Companies Ltd., have awarded contracts to Marconi Instruments for the supply of 250 kV. constant potential X-ray units to their works at Grimesthorpe and Distington, respectively.

The equipment for Grimesthorpe comprises a constant potential high-tension generator, a control unit, an oil cooler, and an oil-cooled shock-proof tubehead, with a special turntable mounting for fitment to a girder suspension system. The Distington equipment is electrically similar, but is mounted on a specially designed two-ton trailer to permit the easy radiographic inspection of welds and castings, irrespective of size. The control unit is installed in a lead-lined protective compartment, while at the opposite end is the tubehead and tubestand.

These equipments have a voltage range of from 30 to 250 kV., enabling steel of up to 4 in. in thickness to be penetrated. The constant potential generators enable the whole of the high voltage energy to contribute to X-ray generation, ensuring maximum X-ray output and, hence, exposure times shortened by half.

After an interval of fifteen years, the registered office of The Mond Nickel Company, Ltd., is once again Thames House, Millbank, London, S.W.1. Early in the war the Company's head office staff were dispersed to various locations in the provinces and suburbs: later they removed to Grosvenor House, London and subsequently to Sunderland House, Curzon Street, which was the registered office until the latest move.

Machine for the Fatigue Testing of Electrical Cable

Pirelli-General Equipment Applies Alternating Bending

WHEN a power cable is loaded with a heavy current its temperature rises and expansion takes place, resulting in an increase in length of the cable. For cables laid in underground ducts this increase has to be accommodated mainly at the manholes, where it is common practice to train the cable into an expansion loop between the two duct-mouths, usually including a rigid straight-through joint. Loading may take place once, or perhaps twice a day, and the cable may thus experience up to 10,000 bending cycles during a lifetime of about 20 years. It is important for cable manufacturers to be able to assess the effects of this repeated flexing on lengths of cable and to be able to compare the fatigue properties of different sheath materials. Pirelli-General Cable Works, Ltd., an Associate Company of The General Electric Co., Ltd., has therefore installed a fatigue bend-testing machine which simulates the thermal movements occurring under service conditions.

Fig. 1.— General view of the fatigue bend-testing machine recently installed at the Pirelli-General Cable Works Ltd.

Design Features

The framework of the machine is constructed from welded mild steel angle sections, and is designed so that loads are taken by the front vertical members and the short cross members. The width is made as small as possible, both for rigidity and in order that a bank of machines may be installed in the minimum of space.

Fig. 2.— A fatigue crack in a lead cable sheath produced by cyclic flexing in the Pirelli-General bend-test machine.

Samples of lead or aluminium sheathed cable to be tested are first cut to a length of about 4 ft. 3 in. and then bent accurately into an arc of 3 ft. radius. The cable is secured to the machine by two pairs of clamps, the lower pair of which is mounted on a steel hub which contains two 5 in. diameter ball races located on an eccentric. Another eccentric is mounted on the output shaft of a gear box, and the two can be clamped together. Each eccentric has a throw of $\frac{3}{4}$ in., and by rotating one with respect to the other the total throw can be varied from zero to $1\frac{1}{2}$ in., the cable being free to pivot about the axis of the ball races. A similar pivot having no eccentrics is mounted at the top of the machine; the upper end of the test length of cable is clamped to it and is thus free to pivot about a horizontal axis. A three-phase electric motor is used to drive the machine through an integral multiple-stage spur reduction gear box which has a specially strengthened output shaft. The rotation of the eccentric causes the distance between the pivots to vary harmonically, resulting in flexing of the cable at a frequency of 9 cycles per minute. The line joining the centres swings about a vertical axis, but this in no way affects the strains in the cable specimen, and as there is no sliding mechanism little accurate machining is required.

Operation of the Machine

Once the machine has been set in motion with the specimen in position it can be left to run unattended until

failure takes place. This is achieved by sealing the ends of the cable with brass caps fitted internally with P.V.C. bushes held in compression against the sheath. The upper cap is connected to a compressed air supply and the system is placed under an air pressure of 10–20 lb. per sq. in. before the test is begun. When failure of a sheath occurs the resultant drop in pressure caused by leakage through the crack operates a pressure switch and trips the motor starter. Since the volume of air in the cable may be very small, a reservoir is used to delay stoppages caused by small leakages from pipe connections. The pressure switch can be short-circuited by a dolly switch for use when the air pressure device is not needed. The number of cycles received by specimens before failure is recorded by an electric counter operated by the lower pivot.

The degree of strain imposed on a test specimen of a particular diameter can easily be varied by adjustment of the stroke of the eccentrics.

The pre-set values are checked by taking strain gauge measurements at the mid-point of the specimen during tests.

The cable samples normally subjected to fatigue bend-testing have a nominal diameter of 1·6 in. The machine can, however, be adapted to take larger or smaller diameter specimens ; in the case of smaller cables, it is possible to accommodate two specimens side by side on a single machine. The frequency of cyclic flexing is known to have an effect on the number of bends which some materials will withstand ; part of the investigation will therefore be devoted to an examination of this effect by varying the speed of operation of the machine and correlating the results with fatigue life.

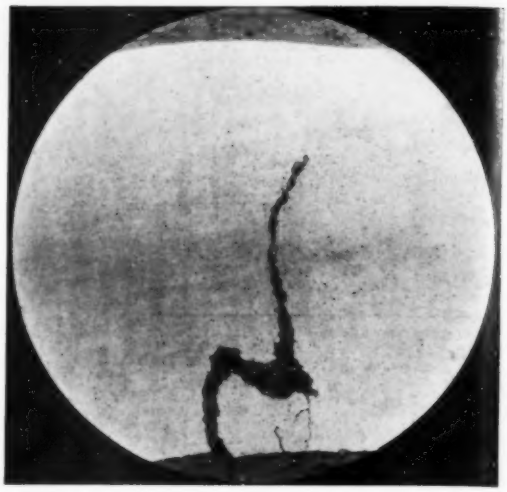
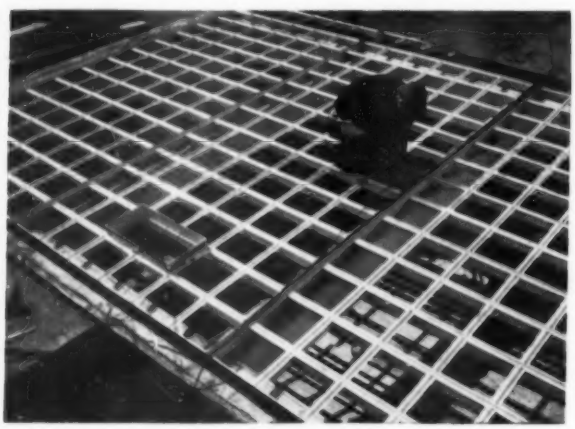


Fig. 3.—Photomicrograph of a fatigue crack in an aluminium cable sheath produced by cyclic flexing.

Aluminium Glazing Bars for Public Baths Roof

WHEN the re-glazing of the roof of Leyton Public Baths, London, became an urgent necessity early this year, the Borough Council adopted the recommendation of its technical officers to replace the badly spalled reinforced concrete glazing frames with frames of extruded aluminium glazing sections. After 20 years' service, reinforced concrete bars supporting the one inch thick glass paving bricks, began to break up, and inspection showed that the steel reinforcing rods, suffering badly from corrosion, had expanded causing spalling of the concrete. Special netting was fixed to avoid the possibility of pieces of concrete falling and endangering swimmers and others using the building, which like many more throughout the country is not confined exclusively to that form of recreation, but is also used for a variety of activities such as dancing, boxing and indoor bowls.



The use of aluminium as an alternative to reinforced concrete or steel was recommended on the grounds that the metal was ideal for this type of application, being light, strong, extremely durable, and resistant to corrosive attack. Because of the corrosion resistance aluminium glazing bars require no painting or maintenance. Presenting a bright appearance when installed, they compare favourably in cost with those in alternative materials, and in many cases the initial outlay involved is actually less.

The work was carried out by Aluminium Construction, Ltd., Woking, and, in conjunction with the Development Division of Northern Aluminium Co. Ltd., glazing sections were designed, and produced in Noral 50SWP alloy, to carry the 12 in. square paving glasses, each weighing approximately 10 lb. The area of the re-glazed portion of the roof measures 143 ft. × 40 ft. and two main sizes of aluminium frame, weighing approximately 2 cwt. each and measuring 13 ft. 4 in. × 6 ft. 2 in. and 13 ft. 4 in. × 8 ft. 2 in., respectively, were designed and tested to carry, in addition to the dead load, a superimposed snow load of 30 lb./sq. ft.—this representing a snowfall 2 ft. deep. At the same time the frames were sufficiently flexible to be shaped to the slight convex curve of the roof, and to allow them to be installed on site without pre-forming.

Aluminium patent glazing bars and window frames that have been in use for over 25 years in various environments, including public baths, are still giving satisfactory service.

The Structure and Mechanical Properties of White Irons

By W. J. Williams, M.Sc., A.I.M.*

Specimens of white iron, even when cast from the same melt may show a scatter in mechanical test results of as much as ±20% of the average value. In this paper the author deals briefly with the structure of white irons, and with the way in which changes in structure are likely to influence the mechanical properties.

ALTHOUGH the output of white and chilled iron is small compared with that of grey iron, it constitutes an important section of the total production. The carbon in white irons exists in the combined form as the compound Fe_3C, or cementite, and it is the presence of this hard and brittle constituent, with a hardness which has been variously reported as being between 990 D.P.N. and 1600 D.P.N., which confers on white and chilled irons their characteristic mechanical and physical properties. They are particularly resistant to deformation under local loading and have excellent wear resisting properties.

White irons are used where their mechanical properties are of some importance, but the amount of information available on these mechanical properties is relatively limited compared with that on grey irons. This is due primarily to the difficulty of machining these irons, and also of producing sound castings.

A study of the mechanical properties of white irons at the B.C.I.R.A. has shown that although major changes in structure due to changes in composition influence the mechanical properties, there is also a difference in the mechanical properties of test specimens cast from the same melt. This scatter in results, which amounts to as much as ±20% of the average value, appears to be peculiar to white cast iron, and has been related to a difference in fracture appearance, and also to a less obvious difference in microstructure. It is the purpose of this paper to deal briefly with the structure of white irons, and with the way in which changes in structure are likely to influence the mechanical properties.

* Formerly of the Research Staff, British Cast Iron Research Association

The Structure of Hypo-Eutectic White Irons

Commercial white irons are usually hypo-eutectic in composition, that is, they have a carbon equivalent of less than 4·3%. A typical microstructure is shown in Fig. 1, and at a higher magnification in Fig. 2. Transformed primary austenite dendrites can be seen in a eutectic matrix consisting of a fine dispersion of transformed austenite in cementite. The primary austenite dendrites constitute the first phase to form from the liquid, and develop over a temperature range down to the eutectic temperature. The white iron eutectic complex then solidifies at the eutectic temperature to form the matrix.

It is convenient for the purpose of a discussion of the microstructure of white irons to consider the primary dendrite and eutectic structures as separate features, since factors which influence one do not necessarily influence the other.

Factors Influencing the Structure of the Primary Dendrites of a White Cast Iron

The proportion of primary dendrites in a white cast iron varies with the carbon equivalent and, since white irons are low in silicon and phosphorus, it may be said

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Fig. 1.—Showing primary dendrites and well-developed ledeburitic structure in a hypo-eutectic white iron. Etched 4% picral. ×100

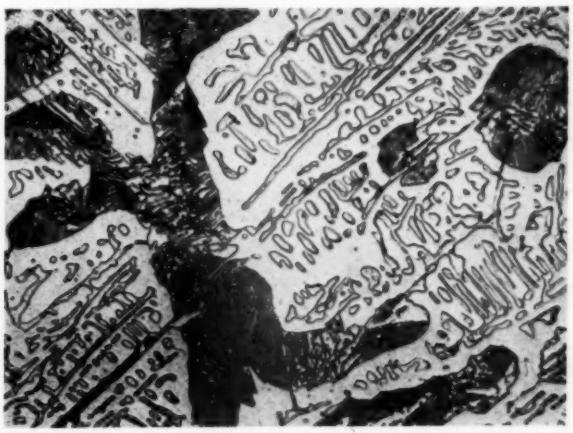

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Fig. 2.—Showing same structure as Fig. 1 at a higher magnification. Etched 4% picral. ×600

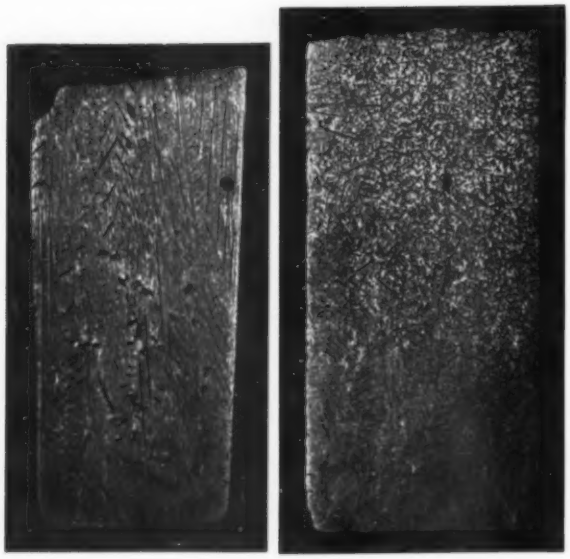

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Fig. 3 ×5½ Fig. 4 ×5½

Fig. 3.—Showing large dendrites in chill test cast at 1,420° C. Vertical illumination. Etched 5% nital.

Fig. 4.—Showing small dendrites in chill test cast at 1,270° C. Vertical illumination. Etched 5% nital.

that it depends on the carbon content. The higher the carbon content the less the proportion of primary dendrites and the greater the proportion of eutectic. There is at present no evidence that the dendritic habit of the primary dendrites can be altered by physical factors, or by the introduction of a third element into the iron-carbon system. There is a general coarsening of the structure with slower rates of cooling, but the major change in size and direction of growth of the dendrites is that which is produced by altering the casting temperature. The change in the primary dendrite structure produced by casting a hypo-eutectic iron against metal chills is shown in Figs. 3 and 4, which illustrate macro-sections taken at right angles to the chilled face. Fig. 3 shows the dendrite structure in the test block cast at 1,420° C. and Fig. 4 that in the block cast at 1,270° C. The casting temperature has an effect on the form of the primary dendrites, even in the regions remote from the action of the chill plate, where the temperature gradient is not so marked. The primary dendrites in the material cast hot are relatively long, whereas in material cast cold, they are shorter.

The effect of casting temperature on the microstructure and fracture appearance of hypo-eutectic and hyper-eutectic white irons has been studied by Norbury,[1] who was able to show that the big difference in primary dendrite structure had no discernible effect on the fracture appearance of hypo-eutectic irons.

Norbury observed, however, that there was a definite relationship between the coarseness of the primary carbide needles and the fracture appearance of hyper-eutectic white irons. Hyper-eutectic irons have a carbon content in excess of that which would result in a carbon equivalent of 4·3% and, by an appropriate alloy addition, such as manganese or chromium, the primary phase consists of large plates of iron carbide. Norbury showed that the effect of casting temperature on such irons was analogous to that with hypo-eutectic irons. The effect of casting temperature on the primary carbide structure is shown in Figs. 5 and 6, where Fig. 5 illustrates the macrostructure of an iron cast hot and Fig. 6 that of an iron cast pasty. There is a decrease in the size of the carbide plates with decreasing casting temperature. Figs. 7 and 8 illustrate how these changes in macrostructure affect the fracture appearance, where Fig. 7 illustrates the fracture appearance of the test block cast hot and Fig. 8 that of the one cast pasty.

Summarizing the salient features at this stage, it may be said that the proportion of primary dendrites in a hypo-eutectic iron is determined largely by the carbon content, and that the size and pattern of these primary dendrites are influenced by the cooling rate and casting temperature. The same comments apply to the primary carbide plates in hyper-eutectic irons.

The hypo- and hyper-eutectic irons differ with respect to the influence of these changes in primary structure in each case on the fracture appearance. The fracture

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Fig. 5.—Showing large primary cementite needles in a hyper-eutectic white iron, cast hot. Etched 4% picral. ×15

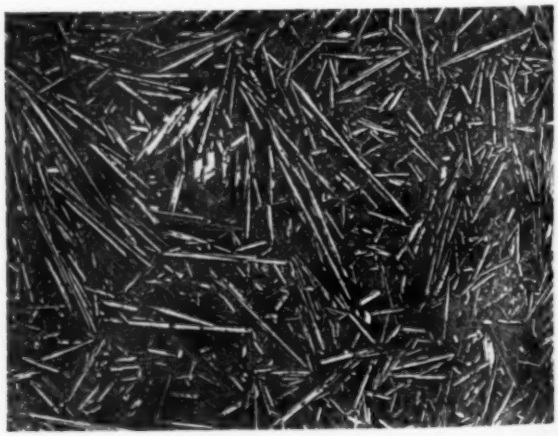

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Fig. 6.—Showing small primary cementite needles in a hyper-eutectic white iron, cast pasty. Etched 4% picral. ×15

appearance of hypo-eutectic irons is not affected by the changes in primary dendrite structure produced by changes in casting temperature, whereas the fracture appearance of hyper-eutectic irons is affected by the change in primary carbide plate structure produced by such changes. It may, therefore, be concluded that the fracture appearance of white irons is governed by the carbide phase.

The Eutectic Structure of White Irons

The cementite in hypo-eutectic white irons forms together with austenite at the eutectic temperature. A mixture of cementite and transformed austenite, usually referred to as ledeburite, is shown in Figs. 1 and 2, where it forms the matrix surrounding the primary dendrites. The cementite, which appears as the white constituent, is the continuous phase of the eutectic.

Not all hypo-eutectic white irons have this well developed eutectic-like ledeburitic structure. The ledeburitic structure shown in Figs. 1 and 2, which was produced in a pure iron-carbon alloy, can be changed completely by the addition of sulphur to give the structure shown in Fig. 9. This change from the ledeburitic eutectic structure, where the cementite forms the matrix or continuous phase, to the plate-like or massive carbide structure, where the carbide is less continuous, was produced in this case by the addition of 0·1% sulphur[2]. The angular or plate-like form of the carbide is shown at a higher magnification in Fig. 10, where it will be seen that the transformed eutectic austenite, which is distributed throughout the cementite in the ledeburitic structure shown in Fig. 2, has been precipitated on the primary dendrites, thus masking their original contours.

A similar change in structure is produced in pure iron-carbon alloys by the addition of iron oxide[2], and also by the addition of phosphorus[3]. The effect of phosphorus is shown in Figs. 11, 12 and 13, where the compositions are as follows :—

Fig. No.	11	12	13
Total Carbon	3·6%	3·6%	2·8%
Phosphorus	—	0·25%	0·39%

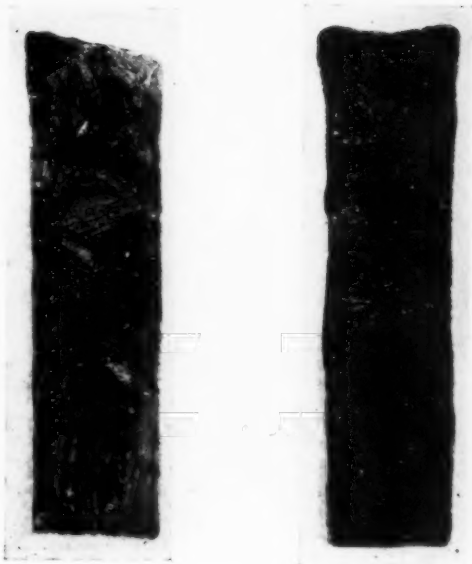

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Fig. 7.—Cast hot. ×½ **Fig. 8.—Cast pasty ×½**

Figs. 7 and 8. Vertical fractures of hyper-eutectic white iron test blocks cast on chills. (T.C., 4·56% ; S, 0·32% ; Mn, 0·7% ; and Cr, 4·5%).

The progressive elimination of the characteristic ledeburitic structure with increasing phosphorus is easily recognised.

Relationship of Microstructure to the Mechanical Properties of White Irons

The Association's work on the mechanical properties of white irons has shown that there is a considerable scatter in results between test bars cast from the same melt under identical conditions. It has been established that this scatter, which can amount to ±20% of the mean value, is not due to unsoundness or defects in the testing procedure. This scatter in mechanical results makes an

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Fig. 9.—Showing massive eutectic carbide produced in a hypo-eutectic iron-carbon alloy by 0·1% sulphur. Etched 4% picral. ×100

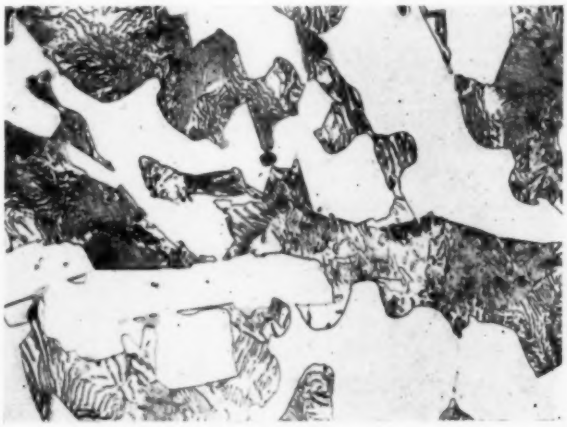

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Fig. 10.—Showing same structure as Fig. 9 at a higher magnification. Etched 4% picral. ×600

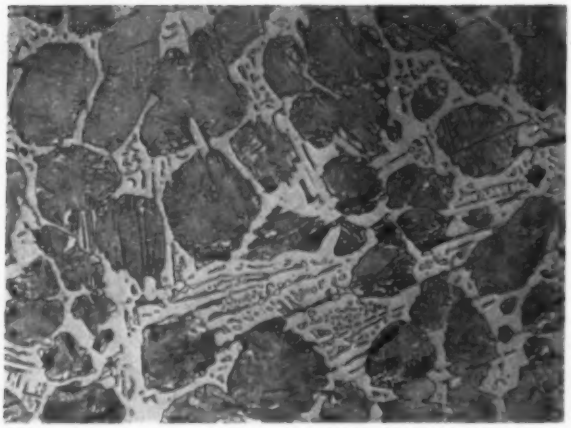

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Fig. 11

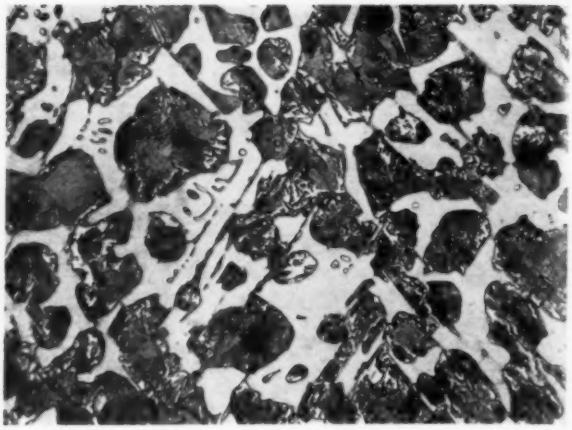

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Fig. 12

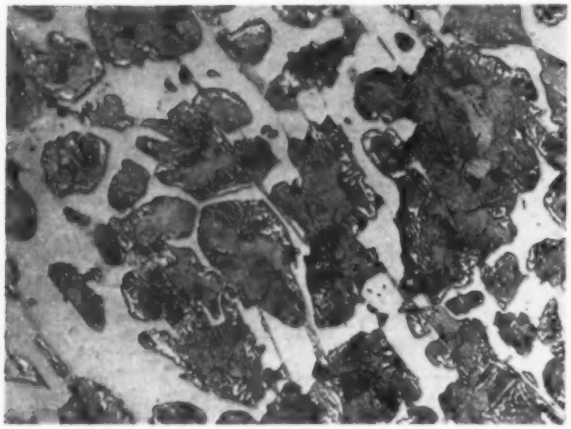

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Fig. 13

Fig. 11.—Showing predominantly ledeburitic structure in a hypo-eutectic white iron containing no phosphorus. Etched 4% picral. ×300

Fig. 12.—Showing predominantly massive carbide structure in a hypo-eutectic white iron containing 0·25% phosphorus. Etched 4% picral. ×300

Fig. 13.—Showing massive carbide in a hypo-eutectic white iron containing 0·39% phosphorus. Etched 4% picral. ×300

Fig. 14.—Macrostructure of a white iron having a fine fracture. Oblique illumination. Etched 4% picral. ×6½

Fig. 15.—Macrostructure of a white iron having a coarse fracture. Oblique illumination. Etched 4% picral. ×6½

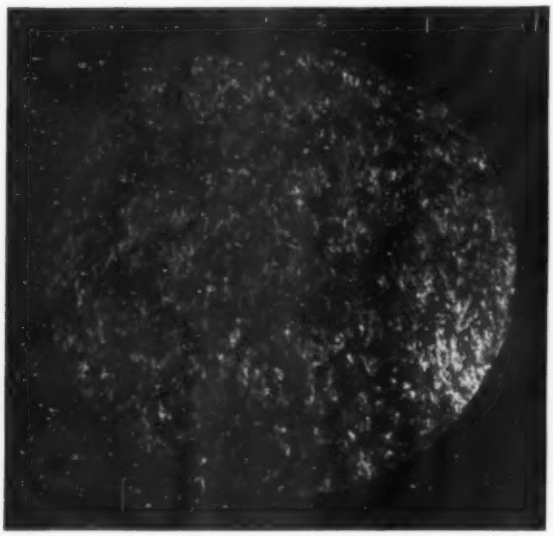

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Fig. 14

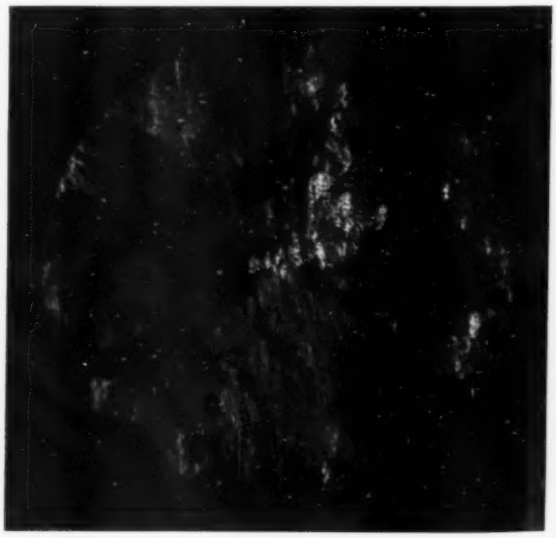

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Fig. 15

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Fig. 16.—Macrostructure of a white iron having a fine fracture. Vertical illumination. Etched 5% nital. ×6½

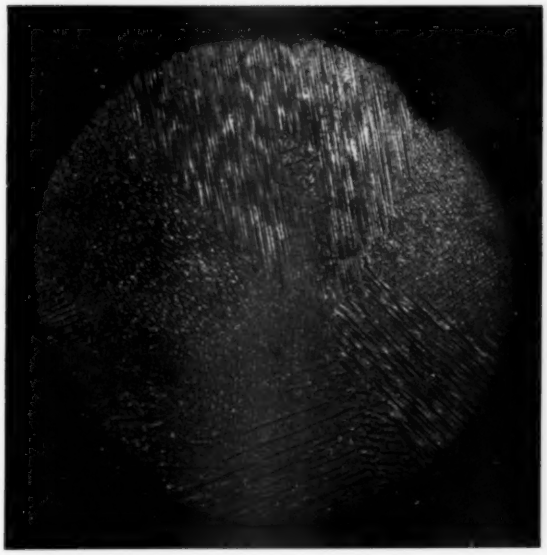

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Fig. 17.—Macrostructure of a white iron having a coarse fracture. Vertical illumination. Etched 5% nital. ×6½

investigation of the effect of composition a matter of some difficulty, requiring the testing of a large number of specimens from each composition. A value given for any particular one test could be extremely misleading.

It has been observed that there is a correlation between the mechanical test properties and fracture appearance. Examination of a large number of specimens has shown that, from every set cast from the same melt, some bars have a fine fracture and some a coarse fracture, with many having intermediate types of fracture. The test specimens with the fine fracture give the highest mechanical properties and those with a coarse fracture the lowest. The scatter in test results appears to be due to this feature, which, as far as is known at present, is uncontrollable and occurs consistently in a wide range of compositions. The difference in fracture appearance and hence, mechanical properties, occurs in test bars cast from the same ladle, and even in the same mould.

The difference in fracture appearance is also revealed in the macrostructure. Fig. 14 shows the macrostructure of a white iron test specimen with a fine fracture appearance and having an ultimate tensile stress of 30·5 tons/sq. in., whilst Fig. 15 shows the macrostructure of a test specimen with a coarse fracture appearance and having an ultimate tensile stress of 20·3 tons/sq. in., which was cast from the same ladle of metal. The fine grained appearance of the high strength material and the coarse grained appearance of the low strength material are immediately apparent.

These test bars were cast at the same temperature, which was fixed at 1,420° C., and it is, therefore, not surprising that the primary dendrite structures, shown

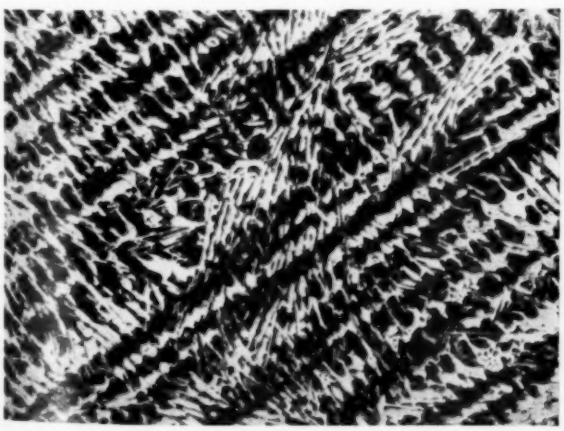

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Fig. 18.—Microstructure of a white iron having a fine fracture. Etched 5% nital. ×100

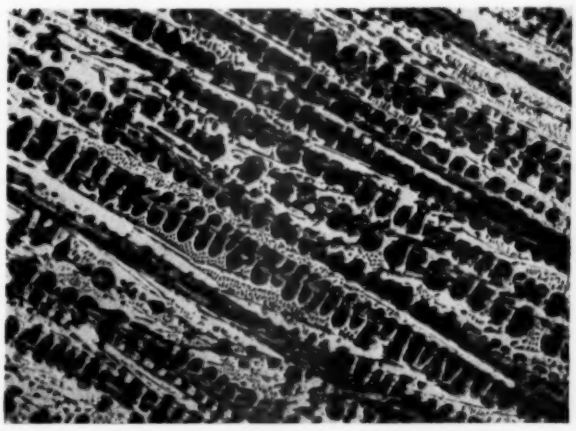

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Fig. 19.—Microstructure of a white iron having a coarse fracture. Etched 5% nital. ×100

in Figs. 16 and 17, were of the same order of size in each case. Since it is the iron carbide which determines the fracture appearance, the reasons for the differences in fracture appearance and mechanical properties must be sought in the structure of the eutectic. The microstructure of the fine fracture iron is shown in Fig. 18 and that of the coarse fracture iron in Fig. 19. It will be observed that the fine fracture material shown in Fig. 18 has a predominantly non-ledeburitic structure, whereas the coarse fracture material has a predominantly ledeburitic structure.

This feature is not necessarily the principal difference. White irons containing more than usual amounts of phosphorus also show a scatter in the mechanical properties, with corresponding variations in fracture appearance, but their microstructures are all predominantly non-ledeburitic in form. It is most likely that the principal feature determining the fracture appearance in Fig. 18 is the relatively discontinuous nature of the cementite particles, and the accompanying frequent changes in orientation of the carbide plates due to these groups of eutectic cells. Thus there are a greater number of cells or units where the carbide plates have the same orientation in Fig. 18, than there are in Fig. 19 where there appears to be only one general orientation. Careful examination of the microstructure shown in Fig. 19 shows that there is a tendency for the plates to be parallel to the direction of the dendrites, but this is not always the case, and the direction of growth of the eutectic carbide is usually independent of the orientation of the primary dendrites. The structures shown in Figs. 18 and 19 would suggest that eutectic solidification commenced at a larger number of points in the fine fracture iron than in the coarse fracture iron.

The appearance under oblique illumination of the polished and etched surfaces of the specimens shown in Figs. 14 and 15 is due to the influence of these groups of carbide plate surfaces having the same orientation, and standing slightly in relief after etching, on the reflection of the light incident upon the surfaces.

The large continuous areas of eutectic cementite plates shown in Fig. 19 provide paths for the propagation of cracks over a considerable distance, without change of direction, and so yield a coarse fracture. The progress of the fracture path for the structure shown in Fig. 18 would be retarded by frequent changes in direction and would result in a fine fracture.

The reason for these variations in structure is not understood. It represents a new finding and indicates that white irons may be subjected to the same complexities as are grey irons. The fine fracture might result when solidification of the eutectic begins at many points, and the coarse fractures when solidification begins at a few points. This has not been definitely established, and future work will need to be concerned with determining the cause of this apparently uncontrollable variation in structure. Some considerable importance must be attached to it, since if the fine structure could be produced deliberately it would offer a means of improving the mechanical properties of white irons.

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2. Williams, W. J., *Journal of the Iron and Steel Institute*, 1950, **164**, 407–422.
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Rolling Mill Drive Order

An interesting and important order for rolling mill plant has been received recently by British Thomson-Houston, to replace one of their older machines which has already done 36 years service. In 1919 B.T.H. supplied to Steel, Peech & Tozer of Sheffield a 6,000-h.p. reversing cogging mill drive. The mill driven by this motor has been one of the busiest in the country and has broken many records for output. Some years ago it was completely modernised but the old B.T.H. drive was retained. During its long service this drive has been working 24 hours a day, 5½ days a week, on the most arduous duty, and is still going strong.

The mill owners, however, conscious that equipment cannot be expected to stand up for ever to such arduous duties, and recognising that a major breakdown would be a disaster, have decided to replace the old by a completely new drive. After careful consideration it was decided to increase the horsepower to 7,000 to cater for still greater mill demands to be expected in the future. B.T.H. engineers, fully exploiting improved designs developed since 1919, have been able to offer a motor of the required 16½% larger rating to go on the existing baseplate; this will be a great advantage in shortening installation time at the changeover. The full rating of the new motor is 7,000 h.p., 50/100 r.p.m., 1,500 volts, with a cut-out rating of 21,000 h.p. The motor-generator set being supplied with it has a 5,000-h.p. induction motor, three 1,867-kW, 500-volt generators, and a 30-ton flywheel.

The control gear, of the latest B.T.H. design, will be capable of very high rates of reversal. For instance, it will be possible to reverse the mill motor, the armature of which weighs 100 tons, from 50 r.p.m. in one direction, to 50 r.p.m. in the other direction in 1½ seconds. In service it will have to do this about ten times a minute, day and night continuously; which means that 100 tons will be reversed in direction on an average every 6 seconds.

New Hungarian Foil Mill

A new aluminium foil rolling mill now being fitted out in Köbánya, Budapest, Hungary, will eventually cover all domestic requirements for the food and chemical industries and do away with the need for imports, the newspaper *Szabad Nép* reports.

The finest-gauge foil (0·009 mm.) will be rolled on mills supplied some time ago by the British firm of W. H. A. Robertson and Co., Ltd., who supplied a roughing mill capable of a rolling speed of 50–150 m./min. a finishing mill of equal speed, and a washing mill to remove oil from the finished foil at 90 m./min. The new factory's pre-tensioning machine was supplied by the Czechoslovak Skoda works. The factory is highly-mechanised, only 20–22 men being required per shift.

Brightside Subsidiary

The Brightside Foundry and Engineering Co., Ltd., announce the formation of a new wholly-owned subsidiary company, Brightside Heating and Engineering Co., Ltd., which has been formed to take over the continuously expanding activities of its Heating, Air Treatment and Pipework Division. Mr. Ambrose Firth has been appointed Chairman, and Mr. T. C. Firth, Mr. W. S. Richards and Mr. W. B. James, Directors.

Railway Axle Production

United Steel's New Forge

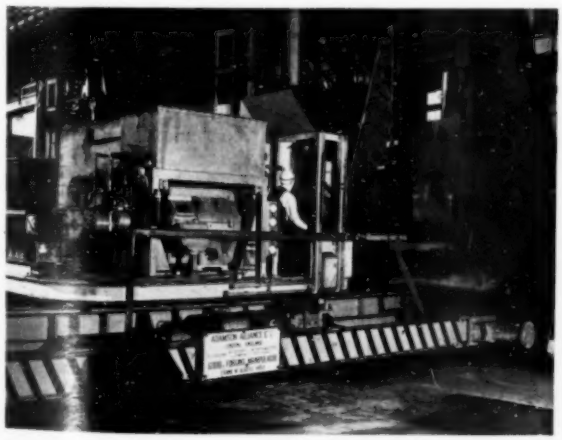
THE United Steel Companies, Ltd., have been major producers of railway materials for many years, a substantial proportion of the output being supplied to British Commonwealth and overseas railways. Included in United Steel's post-war programme for modernising their railway materials departments was the provision of a new axle forge, costing £150,000; this has recently been completed in the Ickles works of Steel, Peech & Tozer, Rotherham. This forge, designed for an output of upwards of 100 axles per shift, takes advantage of the most up-to-date techniques in axle production, and the equipment installed has been laid out to ensure continuous flow of the material during the different stages of manufacture.

The building housing the plant consists of two bays: the main bay, 70 ft. wide by 320 ft. long, and the secondary bay, 55 ft. wide by 240 ft. long. The height to the apex of the roof of the main bay is 65 ft. Particular attention has been paid to the lighting and ventilation. Ample glazing is provided in the slopes of the roof of both bays to supplement the light from the sides and ends of the shop.

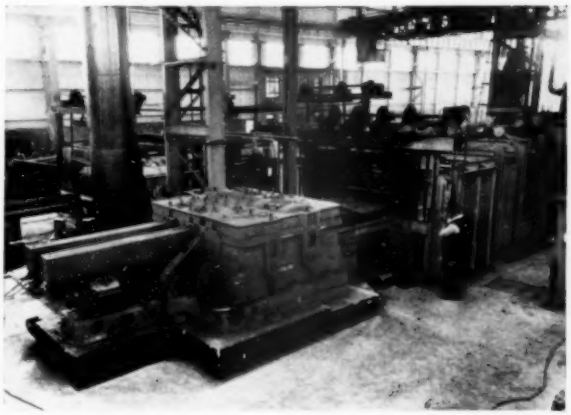
Taken in the order of its use, equipment in the axle forge comprises a 10-ton electric overhead travelling crane; a continuous gas-fired furnace; an electro-hydraulic mechanical manipulator; a 7-ton steam-operated hammer; a heat treatment furnace; a quenching tank; a straightening press; and ending saws.

Continuous Furnace

Axle blooms from the company's Templeborough mills are received in wagons by rail, and are removed by electric overhead crane for stacking adjacent to the continuous furnace. This furnace, built by Wincott has a width of 8 ft. 6 in. and an effective length of 37 ft. 6 in. and is provided with one main end charging door and two side discharging doors which are arranged for simultaneous operation by one valve controlling the hydraulic lifting cylinders. The blooms are pushed down the furnace by an electric pusher, the normal heating period being approximately five hours.



Wagon axle being forged by manipulator under 7-ton hammer.



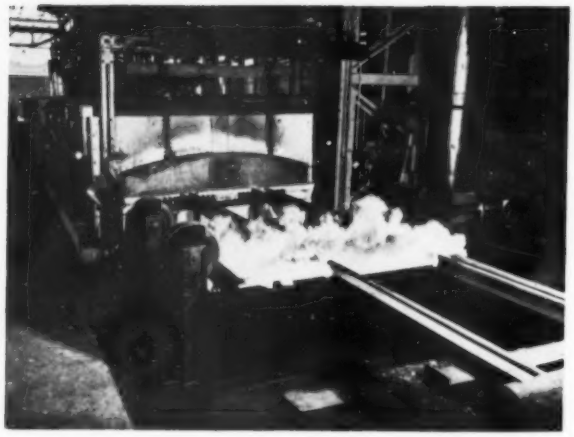
Charging end of the gas-fired continuous bloom heating furnace, showing the mechanical pusher mechanism.

Heating is by low-pressure coke oven gas from five head burners and three secondary burners, each burner having a capacity of 3,500 cu. ft. of gas per hour. Air is supplied by an electric fan, and the furnace is designed to heat 100 blooms, 7⅜ in. square by 56 in. long, from cold to 1,250° C. during a 7½-hour shift. The temperature is controlled by manually-operated gas and air valves, continuous readings of gas and air flow and furnace temperature being recorded on the instrument panel. When it has reached the correct temperature, the bloom is delivered by a friction roll pusher, operating at right-angles to the centre line of the furnace, on to gravity rolls, from which it is picked up for forging.

Forging Process

Throughout the forging process, the bloom is held by an Adamson Alliance 6,000lb. low, straight-line, bridge-type manipulator of the non-revolving type, operating on a track set at 25 ft. centres, 102 ft. long, which runs in front of the 7-ton hammer. The tongs, which can both grip and revolve, receive power for gripping from a revolving hydraulic cylinder; the revolving motion is controlled by an oil hydraulic motor, pressure being supplied from a pump directly connected to a constant speed motor. The operator of the manipulator has an unobstructed view of the work during forging and is protected from heat and flying scale by special heat-resisting safety glass, and from shock by special springing devices.

To reduce long travel motions to a minimum, the turntable necessary to reverse the axle bloom (which is forged at one heat) is mounted on the front of the manipulator frame, and is controlled by an independent pump unit operated by the manipulator driver.



Axle being oil quenched.

For forging, a B. & S. Massey steam hammer of 50 in. stroke and 7 tons rating, with a working pressure of 90 lb./sq. in., is provided. The base plate is cast steel and the 120-ton cast iron anvil block has a 20-ton steel top. Operation of this hammer is by means of the normal controls, with safety devices, the lubrication mechanism being connected to the hand lever so as to give semi-automatic lubrication. Jets of water can be played on the bloom during forging, thus ensuring the removal of all scale and a clean finish to the forging.

When forging of one end of the axle is complete, it is placed by the manipulator on the turntable for rotation through 180°, before forging the other end. Double-grooved fixed swage tools are used, one groove forging the middle of the axle while the other shapes the end collar, journal and wheel-seat.

Heat Treatment

On completion of forging, the axle is placed on a tilting gantry which raises it to the height of the fore-hearth of the heat treatment furnace. Here, it is allowed to cool below the point of recalescence before being charged into the furnace. It rolls through the furnace—which has a sloping hearth 32 ft. long and 11 ft. 8 in. wide—during a period of four hours, and is reheated to 850° C. Heating is by 20 low-pressure burners using coke oven gas. The discharge end of the furnace is fitted with automatic control to assist in regulating the temperature of the axle within fine limits. Both the charging and discharging doors are power-operated by 2 h.p. electric motors.

On leaving the furnace, the axles roll on to a platform above the dipping tank, those which are to be normalised passing straight over on to a turntable. Axles which are to be oil-quenched are retained by four stirrups, into which they drop ; these can be raised between the rails supporting the axles on a platform over the quenching tank. The whole platform is then lowered at 40 ft./min. by an electrically-operated winch into the oil tank, where it is retained for a pre-determined period. Oil in the tank is maintained in the temperature range, 103–153° F. by continuous circulation through coolers, a constant check being maintained on these temperatures. After immersion, the platform is raised, the rails lifting the axles clear of the groove bars, thus enabling them to roll on to the turntable. The turntable is then rotated through 90° and the axles roll forward to the cooling racks.

Straightening and Ending

The straightening press, which has a built-in hydraulic unit, can exert a pressure of 150 tons, and hydraulically-operated spinning rollers are provided to facilitate rotation of the axle during the straightening operation. The ends of the axles are then cut to the correct length by double-headed saws, before passing forward for inspection.

Each axle is given a surface inspection and dimensions are checked. Axles may be loaded either direct into railway wagons for despatch to destination, if required in the " as forged " condition, or on to lorries for delivery for machining, this latter operation being carried out by Owen & Dyson, Ltd., of Rotherham, a United Steel subsidiary.

Ancillary Plant

To cope with demands for axles when, for any reason, the new 7-ton hammer and its ancillary equipment are out of service, an existing 5-ton hammer has been transferred to the new axle forge building. Normally, this hammer operates as an independent unit on general forgings. It is served by two new batch type gas-fired furnaces, situated one on each side of the hammer. Each furnace is served by a 4-ton electrically-operated jib crane with a working radius of 21 ft., the bloom and forging equipment being supported by an endless burden chain.

The plant as a whole makes up an efficient forging unit in which full advantage has been taken of the latest developments aiming at speedy operation, minimum handling and close technical control throughout all the processes.

Permanent Training School for Honeywell Brown

" You have heard instrumentation described as the ' key to industrial progress'. We fashioned that key—now we are training men to use it." This was how Mr. E. C. Vorlander, Managing Director of Honeywell-Brown, Ltd., referred to his Company's recently established training school at Perivale, London. Mr. Vorlander was speaking at a dinner given in London's Cumberland Hotel to mark the end of the school's first nine week course in industrial instrumentation. This course was for ' internal ' training. Half the students were employees of Honeywell-Brown, Ltd. the rest were sent by other European Companies within the International Division of the Minneapolis-Honeywell Regulator Company.

The school is fully equipped to provide intensive training in all aspects of industrial instrumentation. Fundamentally, the aim is to teach, by lecture and laboratory practice, the theory, operating characteristics, industrial applications, and maintenance of the company's instruments and automatic controls. Besides offering customer and basic training courses, the school will keep trained men up-to-date by providing refresher courses as often as possible. Customer courses will commence in the near future and are already heavily booked. Admission enquiries should be addressed to the Company's nearest Branch Office.

Titanium Alloy Production

New Melting Plant Will Extend Jessop Facilities

THE last few years have seen an increasing demand for titanium and for improved titanium alloys. In order to make them more readily available for general industry, William Jessop & Sons, Ltd., of Sheffield, will begin melting this new material on a production basis early next year.

To date, of course, the major consumer of titanium has been the aircraft industry, where its high strength-to-weight ratio, coupled with good mechanical properties and corrosion resistance, is advantageous, particularly in connection with components for gas turbine engines.

Although there are large deposits of titanium-bearing minerals, the metal is costly because of the difficulty of extraction which calls for a very high order of control and inspection. Jessop's experience in the production of metals requiring stringent inspection and testing has been considerable. For over twelve years, in the production of gas turbine components, they have developed the forging of discs and other parts to obtain optimum properties; have perfected ultrasonic and gamma-ray inspection; and have installed 200 creep units of various types to ensure that high temperature strength specifications are met.

With this experience and all their facilities, Jessops felt confident to tackle titanium production, and as early as 1950 had successfully manipulated what was then the largest titanium billet to be imported into this country. In recent years, large billets—melted in America—of up to two tons in weight, a variety of compressor discs of up to 24 in. diameter, rings up to 15 in. diameter, and aircraft take-off hooks have been forged.

In parallel with this large-scale forging, investigations were begun into the development of titanium alloys. An experimental tungsten electrode furnace was built which was capable of producing a 3 lb. ingot of 2½ in. diameter; but, aiming at the most exacting requirement for titanium alloys—turbine compressor application—it was soon felt that a large furnace of improved design was required.

Accordingly, a pilot plant capable of melting 6 in. diameter ingots weighing up to 40 lb. has now been specially designed and built. This enables development work to proceed on improving the creep strength of titanium alloys at 350/400°C., using a criterion of 0·1% total strain in 100/300 hours.

Assured now of the necessary knowledge for the production in quantity of titanium alloys of exceedingly high quality, the company is constructing a new production melting plant. Due to be completed by the end of 1955, this plant is the result of an exchange of ideas with the leading titanium manufacturers in America and is believed to be the most modern of its type. Provision has been made, for instance, for double melting *in vacuo* to ensure freedom from segregation, sound ingots, and low hydrogen content.

Ingots of up to 300 lb. will be produced with a 12 in. diameter, and from 300 to 2,000 lb. with a 20 in. diameter. These ingot sizes will enable all the range of wrought products envisaged to be processed using ideal conditions. The initial output of this plant will be approximately 350 tons of ingots per year, but as it is expected that the uses and applications of this new metal will increase provision has been made for the capacity of the plant to be extended.

Range of Alloys

Within the two main alloy types, *alpha* and *alpha* + *beta*, Jessops will manufacture various grades of titanium under the trade name of Hylite. Not yet a commercial proposition, the *beta* type will be investigated for potentialities. Hylite will be produced in the following ranges :

Hylite 10 (alpha)—commercially pure titanium with a maximum hardness of 150 Brinell. This alloy would be recommended for applications where maximum formability and weldability is desired and mechanical strength is not critical. For applications involving corrosion resistance, this alloy would also be suitable.

Hylite 20 (alpha)—a 5% aluminium, 2½% tin alloy. For applications where Hylite 10 has inadequate strength, this alloy would be selected. It should be noted that, like all *alpha* alloys, Hylite 20 has only moderate tensile strength, but the stability of these alloys, which are readily weldable and do not embrittle under service conditions, commends them for many applications.

Hylite 30 (alpha + beta)—a 2% manganese, 2% aluminium alloy. This alloy is intended to be the "mild

Titanium compressor disc stampings

steel' of titanium metallurgy, and replaces the older commercially pure titanium containing intentional or unavoidable large additions of oxygen and nitrogen.

Hylite 40 (alpha + beta)—a 4% manganese, 4% aluminium alloy. This alloy has found considerable favour in the United States and consequently has been tried in this country. It is suitable for many applications as a compressor disc or blade material.

Hylite 50 (alpha + beta)—a complex aluminium alloy. This alloy has been developed as a compressor disc or blade material, and would be recommended for the highest duty service where Hylite 40 has inadequate strength.

Properties and Processing

Heat Treatment—Alpha alloys cannot be hardened by heat treatment and normally such alloys as Hylite 10 and 20 will be normalised at 600/700° C., to stress relieve them. *Alpha + beta* alloys are responsive to heat treatment, which will vary with the type of application. Freedom from embrittlement under stress can be achieved. For particular applications exceptionally high strength levels can be obtained at the cost of stability.

Creep Strength—Jessops carry out creep tests to low total strains as opposed to the practice of using the easier rupture testing technique, and the early experimental work on American alloys proved the wisdom of employing this method. Further extensive work is in hand on the effect of processing variables.

The chromium steels for turbine work, well-known under the Jessop names H46 and R2 are undoubtedly stronger than the titanium alloys, but when the lower density of the latter is taken into account, the titanium alloys are superior up to about 450° C.

Fatigue Strength—General experience has shown that the fatigue limit of titanium is at least 50% of the ultimate tensile stress at room temperature. At 400° C., the fatigue limit of Hylite 50 should be at least ± 24 tons/sq. in.

Embrittlement under Stress—Considerable concern has been caused by the embrittlement of some of the earlier titanium alloys under service conditions, but after a tensile creep test extending over a period of 500 hours, a specimen of Hylite 50 was fractured then at room temperature, with perfectly satisfactory results.

Corrosion Resistance—Within their useful service range of operation up to 450° C., titanium alloys are completely free from oxidation. Commercially pure titanium is resistant to many corrosive liquids and gases—salt water, aqua regia, nitric acid, boiling acetic acid, gaseous chlorine, etc.

Processing—Satisfactory techniques have been worked out for cold working, welding, machining, and grinding of the alloys which will be available in the following forms: hand forgings; drop stampings; rolled or hammered bar; and ingots or billets for forging. It is anticipated that there will be a demand for sheet, strip, wire, tubing, etc., and plans are made for supplying the new metal in these forms.

Stud Welding on to Small Curved Surfaces

TO facilitate economical mass production of flare pickets, for which a large order has been received by The Mason Engineering Company of Northampton, the Crompton Parkinson Stud Welding Organisation has recently adapted its techniques to enable $\frac{1}{4}$ in. diameter pins to be stud welded to the curved surfaces of $\frac{3}{8}$ in. diameter rods. This application should be of considerable interest to production engineers, for it proves conclusively that stud welding can be carried out with success on curved surfaces of small radius, and it will undoubtedly give rise to many further applications for stud welding in this field, where more costly or less efficient methods are at present in use. The application, moreover, is also of interest as a good example of jig construction for speeding up a repetitive manual task. By the simple method employed, an operator can accu-

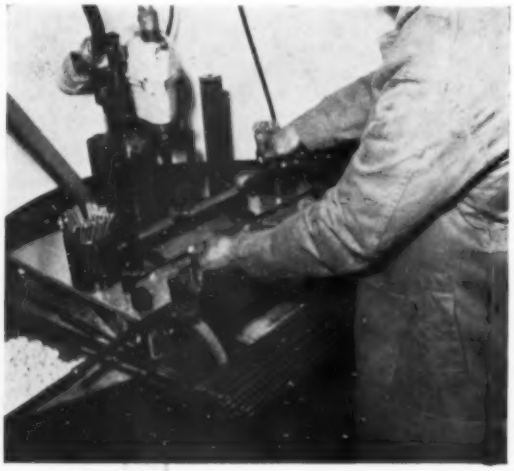


Fig. 1.—Picket rod clamped in jig.

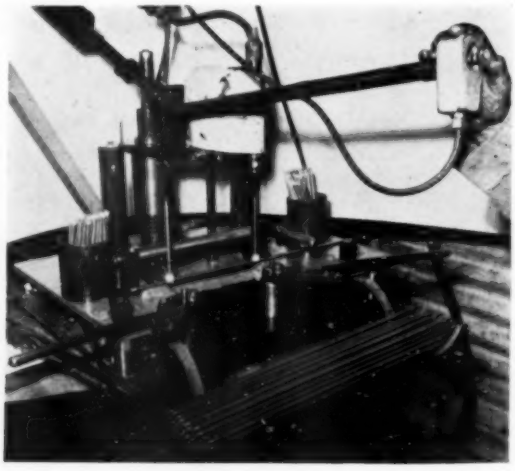


Fig. 2.—Stud welding the right-hand pin, the left-hand pin having been welded previously.

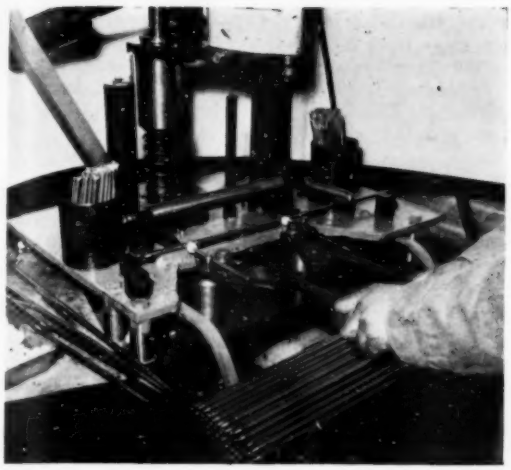


Fig. 3.—Picket rotated, clamped, and ready for bending of the pins.

Fig.4.—Completed picket removed from jig.

rately locate and weld two ¼ in. diameter mild steel pins —5·8 in. and 6·3 in. long respectively—to the 1 ft. 11 in long, ⅜ in. diameter mild steel picket rod, and then bend each pin at right-angles at a pre-set position along its length, all in a " floor-to-floor " production time of only 25 seconds.

Technique

The complete operation is carried out in the following manner. The picket rod, to which the pins are to be stud welded, is placed on vee blocks so that it abuts against an end stop. One of the pins, together with a special concave ferrule, is then loaded into the welding head which is mounted on a swivel above the vee blocks so that it can be lowered to either of the two welding positions, the location of the welding head being by means of pillar slides which limit the swivelling movement; other pillars act as end stops to limit the downward movements. When loaded, the welding head is lowered down the left-hand slide by use of a counterweighted lever, the first weld being effected by pressure on the push button switch which is mounted conveniently on the lever. For the second weld, the operations are repeated with the welding head travelling down the right-hand slide.

The bending of the pins is then accomplished by rotating the picket rod through 90° and clamping it in the vee blocks so that the pins lie flat in a double-handed bending fixture. Operation of the bending device then effects the two right-angle bends simultaneously, and the completed picket is removed by releasing the clamps.

As will have been gathered, the method of producing the flare pickets is extremely straightforward, the work having been reduced to a brief series of extremely simple operations which enable mass produced articles of consistently high quality to be manufactured without any particular skill being required on the part of the operator. For these reasons alone, the combined use of bench-mounted stud welding heads and simple jigs on lines similar to that described is finding increasing favour with production engineers concerned with many products that have hitherto involved either drilling and tapping or some form of arc welding in their construction.

European Steel Pipe and Tube Industry

E.C.E. Study Reveals Fair Prospects

THE conclusions reached by the Secretariat of the United Nations Economic Commission for Europe (E.C.E.), in its second sector study of the European steel industry, dealing with the development and prospects of the steel pipe and tube industry*, are that this industry is in most countries expanding at a rate even greater than that of flat products (which formed the subject of the first E.C.E. sector study): while the industry consumed less than 8% of world crude steel production (excluding U.S.S.R. and Eastern Europe), during the years 1936 to 1938, this proportion rose to over 10% in 1954.

Prospects for the West European tube industry are considered to be fair, and an increase in consumption of the industry's products greater than that of general industrial production is expected. Between 1954 and 1960, West European tube requirements may increase from 3·7 million tons to some 5·1 million, although, the Secretariat adds, this latter figure for both apparent consumption in Western Europe and net exports of tubes may well be substantially exceeded by growing internal and external demand.

Consumption Trends

Per capita apparent consumption of tubes in the U.S.S.R. is now at the same level as in the United Kingdom and Western Germany, and, if indirect exports of

* "The European Steel Pipe and Tube Industry," E.C.E., Geneva, 1955; 103 pages including 28 tables. Available in English and French and later in Russian editions from Sales Section, United Nations, Geneva, at a price of $w.fr. 2.00 or $0.60 (U.S.) and from H.M.S.O., London, for 4s. 6d.

tubes from the latter are taken into account, apparent steel tube consumption in the U.S.S.R. will probably be higher than in those two countries, the study suggests. The probable reason for this is that countries in the earlier stages of rapid industrialisation need vast quantities of tubes for conveying energy and water. If this can be taken as a rule, then demand for tubes in underdeveloped countries may rapidly rise as soon as industrialisation is started. West European producers will benefit only partly from this new demand, since tube mills are being installed in many overseas countries. Part, however, of the expected increase in demand will almost certainly be directed to West European producers.

There is a marked difference in the pattern of tube consumption in the United States and Western Europe. About half of the total tube consumption in the United States is in the form of tubes for oil and gas, whilst the share in Western Europe is only about a quarter, of which two-thirds are exported. In the United States only one-tenth of tubes produced for oil and gas are exported.

Costs and Prices

Between 1938 and 1953, prices of finished tubes have in most major producing countries increased less than wages and the price for tube rounds and skelp (flat strips for making tubes). This has probably resulted mainly from improvements in efficiency, but there is not sufficient material available on either costs or profits to pass any judgment as to how far the high degree of concentration of the tube industry has affected tube prices in the pre-war and post-war periods.

The report points out that the consumer himself has been responsible to a large extent for keeping the costs of tubes higher than they need be, by the multiplicity of sizes and wall thicknesses which he has grown into the habit of demanding. Standardisation may, therefore, be regarded as one of the major premises for price-reductions of tubes, especially since modern tube-making processes are capital-intensive, and can be employed economically only when there is a market sufficiently large for the production of a reasonably standardised line of product. In addition, greater standardisation would show other substantial economies, as for instance the reduction of stocks.

So far, competition by tubes made from alternative materials, such as plastics and asbestos-cement, is not quantitatively very significant, but the output of these types of tubes has been growing rapidly in recent years and the trend is likely to continue, particularly in the case of plastics. This is recognised by many tube makers, who are themselves laying down plastic tube capacity. Although statistical information on comparative prices for steel tubes and tubes made from other materials is scanty, it appears to the E.C.E. experts that steel tubes will well be able to hold their market, especially for tubes with a diameter of more than 2 in.

Pattern of Trade

The two major tube exporting areas are Western Europe and the United States. While West European net tube exports were six times as large as American net exports during the period 1936 to 1938, the relation was only approximately three to one after the war. Nevertheless, West European net tube exports in 1952 and 1953 were more than double the quantity for the years 1936 to 1938. Tube exports can be divided between exports to oil-producing and non-oil-producing countries. The former have always tended to be larger, and from 1951 to 1953 they accounted for about three-fifths of total world tube exports.

One of the four major tube consuming sectors is the oil industry, which has been expanding fairly rapidly in recent years, at a compound rate of somewhat less than 6% *per annum*, and this may be expected to continue at about 5%. Experience suggests that tube consumption in oil production follows a fairly definite pattern: when a new oil-field is discovered, intitial demand for tubes is likely to be high, falling off as oil production rises. The next stage is likely to be again an increase in tube consumption per unit of oil output as drilling goes deeper and strikes become rarer.

Future prospects for tube consumption in oil-producing areas would appear to depend on the result of two conflicting factors. First, the share of supplies from the Middle East and the Far East, where tube consumption per unit of oil output is low, is tending to rise. Against this, it is likely that tube consumption in older oil-producing areas of the world will tend to rise, relatively, as production is extended to less economic districts. As far as oil pipe-lines and refineries are concerned, no particular increase of tube consumption for these purposes can be expected in the near future.

Another large consumer of tubes is the gas industry. As energy requirements increase, gas consumption should at least increase proportionately, especially if economic methods for the total gasification of coal are developed, and more natural gas is produced. The rapid expansion of natural gas production during the past few years, especially in Italy, and increased requirements for gas may well bring about new construction of gas pipe-lines and distribution grids on a larger scale.

Steel pipes and tubes are used in all phases of water distribution. As living standards become higher, tube consumption for water distribution is likely to increase especially, since the industrial share of water usage in Western Europe is still rising, and has not yet reached the percentage it has reached in the United States. Furthermore, all economic programmes in under-developed countries will bring about a substantial demand for steel tubes as water supply is extended for private and industrial purposes, while, on the other hand, tube consumption for water supply in highly industrialised countries may be increased by the growing use of irrigation.

Tube consumption by the construction and related industries depends partly on the level of construction, partly on the scale of amenities provided, particularly in houses, and partly on the degree to which tubular forms of construction are used in substitution for others. As for housing amenities, there are still ample opportunities for improvement as more houses become equipped with sewage, running water, baths, central heating, gas and electricity, etc. This could, of course, be considerably speeded up by appropriate governmental policies. The high rate of construction in Europe provides for a continuing high level of demand for steel pipes and tubes, which is supported by the use of tubular construction on an increasing scale.

NEWS AND ANNOUNCEMENTS

Conference on Steelworks Cranes

A CONFERENCE on E.O.T. cranes organised by the Plant Engineering Division of the British Iron and Steel Research Association will be held at the Hotel Majestic, Harrogate, on October 5th and 6th, 1955, under the Chairmanship of MR. W. F. CARTWRIGHT, D.L., J.P., Assistant Managing Director and General Manager (Steel Division) of the Steel Company of Wales, Ltd. Papers on steelworks requirements for cranes; manufacturers' views; structural design; mechanical features—bearings, couplings, rail wheels, etc.; crane cab layout and design of controllers; electrical equipment; and safety aspects of crane design, operation and maintenance; will be presented by representatives of the iron and steel industry; crane and electrical equipment manufacturers; H.M. Inspectorate of Factories; and B.I.S.R.A.

Although much of the conference will be specifically related to the electric overhead travelling type of crane, other aspects of the subject, such as studies of cab and control design and the techniques of stress measurement, will have a much wider application. An account of the research on cranes carried out by B.I.S.R.A. is contained in B.I.S.R.A. Summary No. 77, a copy of which is available on application to the Information Section, The British Iron and Steel Research Association, 11, Park Lane, London, W.1. The specification for heavy duty E.O.T. cranes for use in iron and steel works has also been revised in the light of this research. Copies of the revised specification will be available in September, prior to the conference. (Charge to non-members, 10s.).

Full particulars of the conference may be obtained from the Technical Secretary, Plant Engineering Division The British Iron and Steel Research Association, 140, Battersea Park Road, London, S.W.11.

Symposium on Phase Transformations

ORGANISED by the Metal Physics Committee of The Institute of Metals, a one-day Symposium on "The Mechanism of Phase Transformations in Metals" will be held at the Royal Institution, Albemarle Street, London, W.1, on Wednesday, 9th November, 1955, beginning at 10 a.m. In all, eighteen papers (mainly describing original work) have been contributed to the Symposium. The morning session will be devoted to transformations of the nucleation and growth type, while the subject for discussion at the afternoon session will be martensitic transformations. Non-members of the Institute will be welcome at the meeting, detailed particulars and a registration form in connection with which may be obtained from the Secretary, Lieut-Col. S. C. Guillan, T.D., 4, Grosvenor Gardens, London, S.W.1.

Increasing Productivity by Welding

THE second of a series of meetings organised by the British Welding Research Association on Increasing Productivity by the Use of Welding will be held on Tuesday and Wednesday, October 4th and 5th, 1955, in the Demonstration Theatre of Electricity House, Colston Avenue, Bristol, 1, by kind permission of the South Western Electricity Board. The topics for discussion on the first day concern ferrous welding and non-destructive testing, and on the second day, light alloy welding and resistance welding.

Admission is by ticket which can be obtained, free of charge from The Organiser, British Welding Research Association, 29, Park Crescent, London, W.1. Owing to the limited accommodation available, intending participants, are asked to state, when applying for tickets, whether they wish to attend on both days.

Steel Delegation to Russia

IN December, 1954, the Soviet Delegation to the Steel Committee of the Economic Commission for Europe were invited to come to the United Kingdom; as guests of the steel industry, they visited a number of steelworks. The Soviet Ministry of Ferrous Metallurgy has now invited a party of steel experts, who attend meetings of the E.C.E. Steel Committee from the United Kingdom, to visit a number of steel undertakings in the Soviet Union.

Her Majesty's Government has been pleased to accept the Soviet invitation and has nominated for the visit a team to be led by Sir Robert Shone, C.B.E., Executive Member of the Iron and Steel Board. The members of the team are: Mr. C. R. Wheeler, C.B.E., (Joint Managing Director, Guest Keen Iron and Steel Co., Ltd.); Mr. W. F. Cartwright (General Manager, The Steel Company of Wales, Ltd.); Mr. A. Jackson (Director and General Works Manager, Appleby-Frodingham Steel Co., Branch of United Steel Cos., Ltd.); and Mr. T. Dennison (Technical Officer, British Iron and Steel Federation).

Institution of Production Engineers Awards

THE Council of the Institution of Production Engineers has announced the following awards:

Silver Medal for the Best Paper presented by a Member, in the 1953–54 *Session:* MR. K. J. HUME, Chief Education Officer of the Dowty Group, for his Paper: "Fundamentals of Gauge Design."

Silver Medal for the Best Paper presented by a Non-Member, in the 1953–54 *Session:* MR. F. NIXON, Assistant General Manager responsible for New Manufacturing Processes, Rolls-Royce, Ltd., for his Paper on: "Effective Utilisation of Materials."

The Hutchinson Memorial Award (Silver Medal) for the Best Paper presented by a Graduate Member, in the 1953–54 *Session:* MR. G. CUBITT-SMITH, Production Officer in charge of Machine Fabrication Department, Crompton Parkinson, Ltd., for his Paper on: "Resistance Welding in America."

The Schofield Travel Scholarship, 1955. Because of the high quality of the candidates, it was decided to award two Schofield Scholarships this year, to: MR. R. W. PICKARD, Technical Assistant to the General Works Manager, C. A. Parsons & Co., Ltd., Newcastle-upon-Tyne, and MR. H. S. WOODGATE, Process Planning Engineer at Fairey Aviation, Ltd., Hayes, Middlesex.

The above Awards will be made at the Annual Dinner of the Institution on Wednesday, 12th October, 1955, at the Dorchester Hotel, London.

Institute of Metal Finishing

WILLIAM JAMES ESSAY COMPETITION

THE Institute of Metal Finishing has decided to revive, in a modified form, the William James Memorial Prize, established in memory of the first Honorary Treasurer, which was allowed to lapse on the outbreak of war. The original competition was designed primarily for students, but, with a view to attracting, in addition, contributions from experienced working electroplaters and metal finishers, the new regulations provide for two sections: (*a*) essays from a theoretical or technical standpoint on any aspect of metal finishing or related subject (age limit 25 years); and (*b*) essays based on practical knowledge or experience of any branch of metal finishing or related subject (no age limit). Further particulars can be obtained from the Hon. Secretary, Institute of Metal Finishing, 32, Great Ormonde Street, London, W.C.1.

Institute of Welding

THE Autumn Meeting of the Institute of Welding will be held in London from November 2nd–4th, 1955. At the Annual Dinner, on the evening of November 2nd, the principal guest will be Mr. F. J. Errol, M.P., Parliamentary Secretary to the Ministry of Supply. Sir Sir Edward Boyle, Economic Secretary to the Treasury has also accepted an invitation to attend. Following the Presidential Address on November 3rd, the remainder of the meeting will be devoted to the presentation and discussion of papers on various aspects of the inert-gas arc welding processes.

The Spring Meeting will be held in the Eastern Counties from 3rd–5th May, 1956.

In September, 1956, the Institute is convening a Conference on the Function and Education of Welding Engineers.

The Council of the Institute has decided to hold a Commonwealth Welding Conference in London in the summer of 1957, with a view to (1) promoting an exchange of information on the present technical position of the welding processes and their main applications within the British Commonwealth; and (2) considering means of improving the exchange of technical information among the countries of the Commonwealth.

It is intended that the conference should be open to all who are interested in welding; invitations to appoint national delegates will be addressed to the welding societies and government departments of the Dominions and Commonwealth territories. An Organising Committee has been appointed, under the Chairmanship of Mr. A. R. Jenkins, J.P.

Lecture Series

A COURSE of four lectures on "Kinetics and Mechanisms in Metal Systems," to be delivered by Dr. R. F. Mehl, Director of the Metals Research Laboratory and Head of the Department of Metallurgy, Carnegie Institute of Technology, Pittsburgh, has been organised by the University of London. The lectures will be given in the Metallurgy Lecture Theatre of the Royal School of Mines, Prince Consort Road, London, S.W.7, at 5 p.m. on Thursday and Friday, October 20th and 21st, and Monday and Tuesday, October 24th and 25th, 1955. The subjects and chairmen on these occasions will be, respectively, Diffusion, (Dr. A. H. Cottrell), Vapour Deposition (Sir Charles Goodeve), Pearlitic Reaction (Mr. D. A. Oliver), and Ferrite, Bainite and Cementite in Steels (Dr. N. P. Allen). The lectures are addressed to students of the University and to others interested in the subject, and admission is free, without ticket.

Science and Management Conference

THE Tenth National Conference of the British Institute of Management will be held at Harrogate from 2nd to 4th November, 1955. Speakers who have already accepted invitations to address the conference include John Diebold, American pioneer of the application of "automation," Sir Geoffrey Vickers, V.C., and Sir Charles Goodeve, O.B.E., F.R.S., Director of the British Iron and Steel Research Association. Provision is being made for 1,000 top managers to be received at Harrogate as delegates to the conference, and a programme is being prepared which will include two plenary sessions and twenty-four sectional meetings devoted to specialised aspects of management.

So fundamental are the changes with which scientists are confronting industry at the moment that many people are already talking in terms of a second industrial revolution. At the same time it is obvious that the face of Britain cannot be transformed overnight. The discoveries of the scientist must be translated into the practice of everyday living, and the responsibility for transferring new knowledge from the research laboratory to the production floor must rest with management. At a time like this it is therefore increasingly important that opportunities should be created for scientists and managers to discuss together the form in which the promised changes should develop, so that the forces of evolution may be speeded and the forces of revolution made effectively productive. The British Institute of Management has therefore chosen as the theme of its National Conference for 1955 "The Impact of Science on Management in the Future."

United Strip and Bar Mills

THE United Strip and Bar Mills, a wholly owned Associate of Steel, Peech and Tozer, whose manufacturing and trading activities have been amalgamated with Steel, Peech and Tozer for many years, has ceased to trade under a separate name and title. Its activities and trading are now carried out in the name of Steel, Peech and Tozer, a Branch of The United Steel Cos., Ltd.

British Technical Aid for U.S.

TAYLOR BROS. & CO., LTD., announce the completion of an agreement to render technical aid to a large United States Corporation which is to instal a new railway wheel manufacturing plant based on the principles and design of that at Taylor Bros., Trafford Park Works, which was described in our December, 1952 issue. Further, there is to be an interchange of engineers between Taylor Bros. and American Rolling Mills Corporation, to ensure that the methods and "know-how" developed at Trafford Park may be incorporated in the new American plant, which is due to come into production in about a year's time. This technical aid agreement adds weight to the belief that Taylor Bros. production unit, where the operators wear white coats and sit in air conditioned rooms, is the most modern railway wheel plant in the world.

In making the announcement, Mr. R. G. H. Taylor, Managing Director, recalled his speech to the press after the opening of the new plant, a few years ago, when he said: "If the Americans were to come to England and see the plant which you have seen today, we might have the Anglo-American Productivity Council working in reverse," and added: "It is a source of great satisfaction that this prophecy has come true."

Personal News

In order to obtain more effective co-ordination between the factory technical departments and to spread the load of the company's expansion programme more evenly, the following changes in organisation and responsibilities have been made at Vauxhall Motors, Ltd.; Mr. F. V. Barker, as Director of Manufacturing, will be responsible for the following departments: Production, Production Control and Standards; Mr. H. T. Johnson, as Director of Planning and Facilities, will assume the direct operating responsibility for the following departments: Forward Planning and Development, Production Engineering, Sheet Metal Production Engineering and Plant Construction and Maintenance; Mr. A. J. Peppiatt, Acting Chief Inspector, will report directly to Mr. J. R. Pearson, Executive Assistant to the Managing Director. Mr. Barker was formerly Director and Factory Manager, and Mr. Johnson was Director of Forward Planning and Development.

Mr. R. H. Collcutt has been appointed Head of the Operational Research Section of the British Iron and Steel Research Association, in succession to Mr. R. T. Eddison.

Birlec, Ltd., announce the appointment of Mr. R. Burges as Publicity Manager, in succession to Mr. J. C. Mantell, M.B.E., with effect from 19th September, 1955. Mr. Burges joins his new Company from Langley Alloys, Ltd., Slough. Mr. Mantell remains within the A.E.I. Group of Companies, in which he will take a two years' training course at The British Thomson-Houston Co., Ltd., Rugby.

Dr. T. Girtin recently retired from the Chairmanship of Johnson & Sons Smelting Works, Ltd. Dr. Girtin joined the Board of the parent company, Johnson, Matthey & Co., Ltd., in 1921 and remained a member until 1952. His appointment to the Chair of Johnson & Sons Smelting Works, Ltd., came in 1930. Amongst his early work for Johnson, Matthey & Co., Ltd., were the reorganisation and integration of the refineries at Hatton Garden, and the building and organisation of the Research Laboratories at Wembley.

British Insulated Callender's Cables, Ltd., announce the appointment of Mr. E. Watt, as their Branch Manager in Chester.

Mr. W. Plumb has been appointed Deputy Commercial Manager for the Liverpool and Netherton Works of The English Electric Co., Ltd. For the last six years, Mr. Plumb has been Manager of the Leeds Branch Office of the Company, where he is succeeded by Mr. A. J. Evans.

Mr. R. E. G. Weddell, Joint Managing Director of W. G. Allen and Sons (Tipton) Ltd. has been elected President of the Institute of Welding for 1955/56, and Sir Charles Lillicrap, K.C.B., M.B.E., former Director of Naval Construction, has been elected Vice-President.

Mr. A. W. Brace has left The Aluminium Development Association to take up an appointment with Aluminium Laboratories, Ltd., as Section Leader of the Metal Finishing Laboratory.

Mr. C. E. G. Bailey, who for some time has been a consultant to The Solartron Electronic Group, Ltd., has been appointed Technical Director of Solartron Electronic Business Machines, Ltd. He will also act in a general advisory capacity on research and development work to the Group.

Kasenit, Ltd., announce the appointment of Mr. W. J. Ratcliffe, son of Mr. J. A. Ratcliffe, the present Managing Director, as Director, Technical Sales.

Mr. P. R. R. Coad, M.C., has been appointed a Director of H. J. Enthoven & Sons, Ltd.

Mr. W. Grainger and Mr. J. Mayer have been appointed Joint Managing Directors of International Combustion (Holdings), Ltd. Both have been with International Combustion, Ltd., for over 30 years.

Dr. N. Gross, at present Reader in Production Engineering at the Imperial College of Science and Technology, London, has been appointed Deputy Managing Director of the Quasi-Arc Co., Ltd. Dr. Gross was formerly Assistant Director of Research at the British Welding Research Association.

Sir Percy Mills, Bt., K.B.E., Chairman of W. & T. Avery, Ltd., has relinquished his appointment as Chairman of the National Research Development Corporation, for business reasons. He is succeeded by Sir Alan A. Saunders, O.B.E.

Samuel Fox & Co., Ltd., announce that Mr. C. E. Lupton has been appointed Secretary and Office Manager. Mr. Lupton was formerly the Statistical Accountant of The United Steel Cos., Ltd.

Mr. P. Smith and Mr. P. Shaw have been appointed Joint Managing Directors of Acorn Anodising Co., Ltd., Acorn Products Ltd., and Acorn & Lumium Sales Co., Ltd.

Mr. L. E. Benson, Chief Metallurgist, Metropolitan-Vickers Electrical Co., Ltd., has been awarded the degree of D.Sc., by the Victoria University of Manchester.

Obituary

We regret to record the deaths of the following:

Sir Charles Bartlett, former Chairman of Vauxhall Motors, Ltd., who died at his home near Harpenden, Herts, on August 10th, at the age of 65. Joining General Motors, Ltd., as a book-keeper in 1921, Sir Charles became Managing Director of that Company in 1926, and of Vauxhall Motors, Ltd., in 1930. He was knighted in 1944, and was Chairman from June, 1953, until his retirement last December. Sir Charles had been ill for many months, and had in fact been far from well since before his retirement.

Mr. F. G. Penny, Managing Director of International Combustion (Holdings), Ltd., Chairman of Aberdare Cables (Holdings), Ltd., and a Director of many other companies, who died at Derby after a short illness, on August 6th. Mr. Penny, who was 66 years of age joined International Combustion, Ltd., in 1926, as Manager of the Field Staff. He was later appointed Chief Engineer and General Manager and elected to the Board and then, in 1951, to the position of Managing Director.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

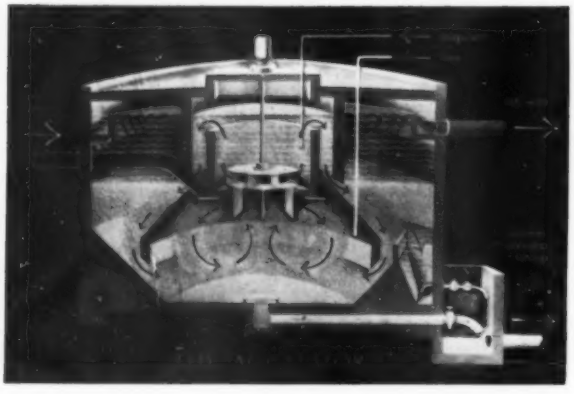
Water Treatment Plant

Suspended matter, iron and manganese, calcium and magnesium and organic colour are all detrimental to many processes which use water as a carrier or in direct contact with their product. Metal processing plants need treated water for rinsing metal parts after pickling or plating.

The Accelator plant manufactured by the Paterson Engineering Co., Ltd., incorporates the novel idea of actually allowing precipitation to occur in the presence of comparatively fresh pre-formed slurry, and means are provided for circulating this fresh slurry with the water being softened. Furthermore, provision is made for maintaining this sludge bed in a mobile condition, and in such a manner that it actually squeezes the softened water from the bed, thus giving a relatively clear softened water in the upper part of the plant.

In general, the plant consists of a vertical and relatively wide diameter main outer steel plate cylinder containing an inner reaction portion, formed also of steel plate. The raw water enters by an inlet pipe at the side of the main cylinder and passes to what is known as the agitator hood, a wide-diameter circular closed chamber in the lower part of the main cylinder with a top hood or cover. The upper portion or extension of this hood is a vertical jacketed cylinder of lesser diameter, reaching almost to the top of the main cylinder, and is known as the secondary main mixing zone, down the centre of which is a vertical shaft driven by a small electric motor at the top of the reduction gear, constituting a vertical paddle shaft. This latter extends to the bottom of the agitator hood chamber, or primary mixing zone, and is provided with agitators of the rotor type.

The chemical reagents (lime and soda ash) enter by a pipe into the top portion of the agitator hood, and the action of the agitator gives instantaneous and intimate mixing of the raw water with the reagents and also the slurry, which is forced up into the upper secondary mixing zone by the action of the rotor agitators immediately below. Also at the top of the secondary mixing zone coagulant solution (aluminium sulphate or sodium aluminate) is added continuously where a more or less gentle agitation is given by the simple agitators already mentioned, operating in conjunction with the baffles.



Normally the lime and soda solutions are added in the form of a magma, but if required they can be added separately so that in the case of a variable water the dose of either lime or soda can be altered independently of the other. The speed at which the softening process is carried out by the Accelator is shown by the fact that when samples are taken from the top of the centre tube it is found that the reaction is almost complete. A sample of circulating slurry from the centre tube, when allowed to settle in a cylinder, starts to clear in a matter of seconds, and within five minutes the supernatant liquor is brilliantly clear.

The Accelator plant is capable of softening a raw water of high calcium and magnesium hardness to give a clear stable filtered water low in hardness and with low excess alkalinity. The plant responds readily to variation in chemical dosage, and the rapid settlement of the slurry shows how successfully the seeding principle has been applied to lead to the formation of large aggregates of considerable mechanical strength.

Paterson Engineering Co., Ltd., Windsor House, Kingsway, London, W.C.2.

Nimonic 100

CLOSELY following on their recent announcement of new production developments which made it possible to produce cooled blade sections in the Nimonic alloys, Henry Wiggin & Co., Ltd., have now released preliminary information on a new alloy in the series known as Nimonic 100.

Like the previous alloys, Nimonic 100 was developed in the research laboratories of The Mond Nickel Co., Ltd., and marks a further successful stage in the continuous research effort which has been devoted to the investigation of high-temperature problems and their solution.

Following its successful testing in the laboratory, intensive production development had to be undertaken in order to make the new alloy available to gas turbine builders in production quantities. The fact that quantities of Nimonic 100 have now been supplied to several gas turbine builders for complete evaluation in actual engines is a remarkable tribute to the skill of the production staff and operators of Henry Wiggin, especially when it is realised that, with each new alloy, the operating temperature at which the material must be tough and stiff, approaches more closely the temperature at which the alloy can be worked.

Nimonic 100 has very high resistance to creep, and may be used at temperatures some 30° C. higher than those permissible for previous alloys in the Nimonic series. The properties given in Table I, as in the case of

TABLE I. STRESS TO RUPTURE PROPERTIES OF NIMONIC 100.

Temperature ° C.	Stress (tons/sq. in.) for Rupture in		
	50 hours	100 hours	300 hours
870	13·5	12·0	9/5
925	8·5	7·0	5·5
940	6·7	6·0	4·5
980	4·0	3·5	3·0

those previously quoted for other Nimonic alloys, may safely be taken as a basis for design calculations. During the past few years, temperature for fracture in 100 hours has been increased to give an effective rise in operating temperature of about 80° C. For Nimonic 80A, the temperature was 870° C., for Nimonic 90, 900° C., for Nimonic 95, 925° C. and for Nimonic 100, 950° C.

Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

Photographic Silver Recovery

The photographic industry is the largest user of silver in the world, and a larger proportion of this silver—the cost of which is of course included in the price of plates and films—is literally thrown down the drain, as a spent fixing bath. Without any great complication, metallic silver can be reclaimed from the used solution, and the bath regenerated, so ensuring consistency of fixing, and economy in hypo.

There are several methods of silver recovery, but the simplest is by electrolysis. The operation is a little critical since any excess of voltage may lead to sulphiding, resulting in impure silver and imperfect fixing. Any such risk is however obviated by the control circuit incorporated in the Purhypo equipment, which, it is claimed, is probably the most widely used silver recovery system in Europe. It is used by film laboratories, D.P. stations, and the photographic and radiological departments of factories and hospitals (X-ray plates, and films are particularly rich in silver.).

Various types of Purhypo equipment are available, from apparatus which fits into existing fixing tanks, to plant capable of handling the enormous output of film laboratories, and needing the installation of a number of special tanks. The equipment is not sold, but is supplied and installed free of charge; the silver recovered is collected, and 50% of the value is credited to the user.

Further details can be obtained from the sole agents.

D. Pennellier & Co., Ltd., 28, Hatton Gardens, London, E.C.1.

Spray Painting Plant

THE Bullows PR.303E spray painting plant has now been available for three years, and at the present time, there are some 5,000 giving very satisfactory service in the domestic market. Recently, certain alterations and improvements have been made to the plant in its original form. There have been some failures of the bonded rubber coupling, and this has now been replaced by a claw type coupling, which it is impossible to break or wear out.

The lubrication system is operated by air pressure, and a few cases have occurred where plants have been connected up in such a way that they have operated at a lower pressure than the minimum for safe lubrication. A minimum pressure valve has been designed, and is now fitted as standard to all machines. The effect of this is to make it impossible for even the most careless operator to damage the machine, because, even with the discharge wide open, this valve ensures a safe minimum working pressure.

The machine incorporates a Hydrovane Compressor which is absolutely silent in operation, and all moving parts are submerged in an oil bath, so that wear is virtually eliminated. The compressor with its one-third

h.p. motor, weighs 42 lb., and is easily carried in one hand. The L.800 internal atomisation gun and hose complete the plant.

Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

Metal Strengthened Carbon Tube

The steady increase in the production and application of corrosive liquids intensifies the problem of conveying them by pipe lines. Carbon is the best pipe material, because of its complete resistance to almost all corrosive chemicals, even in the hot state. Unfortunately, it is comparatively fragile when in the form of tubes, and it can normally be used only for low pressures and for short pipe lines. Talbot Stead Tube Co., Ltd., have now perfected a technique for the production of Metica tubing, which is, in effect two tubes; an inner tube of carbon or graphite protected by an outer tube of metal, a combination giving both resistance and high mechanical strength. This tubing is now commercially available, together with special fittings that ensure continuity of carbon in the pipe. The outer tube may be mild, alloy or stainless steel, or some other material such as copper, brass, etc. Metica tubing is made in certain standard sizes and lengths, ranging from $\frac{7}{8}$ in. to 4 in. nominal inside diameter.

Talbot Stead Tube Co., Ltd., Green Lane, Walsall, Staffs.

Arbor Press

THE Staffa 5-ton arbor press has been designed to meet the needs of the light engineering and other industries, and provides an inexpensive yet invaluable addition to any workshop where accurate press work is required. The construction employs steel sections, so that the addition of jigs and other adaptors for specialised needs involves only a simple welding operation. The surface plate is accurately machined and is of generous size.

Used in conjunction with the Staffa Hydroram pump and ram unit, a progressive pressure of up to 5 tons is available at the ram nose. Retraction of the ram after pressing is automatic and requires only a half turn of the release valve. The self-contained pump and ram unit is easily removable and provides a remote jack unit at no extra cost. The interconnecting hose is three feet in length, and thus fulfils many applications in which a standard one piece jack cannot be employed.

Chamberlain Industries, Ltd., Staffa Works, Staffa Road, London, E.10

CURRENT LITERATURE

Book Notice

THE ORGANISATION OF APPLIED RESEARCH IN EUROPE

Proceedings of an O.E.E.C. Conference at Nancy, 11th-13th October, 1954. 204pp. Obtainable from H.M. Stationery Office and other organisations handling O.E.E.C. publications. 12s.

THE increasingly rapid advance of science and technology makes it essential that the problems of organising scientific research should be clearly understood. Scientific research is clearly becoming of growing importance to the economic life of nations: it calls for the best brains they can offer, and for a readiness to stake money on well-considered risks in the same spirit as loans were put up to finance navigators at the time of the great maritime discoveries.

For the first time in Europe, leading representatives of the Universities, industries and government departments of ten European countries, meeting at Nancy under the aegis of the O.E.E.C. have been able to exchange views on the subject of "Organising and Administering Scientific Research." During the first day, they discussed the practical organisation of research and the respective functions of universities, industries and government departments in this respect; during the second day, "human factors" in research; and during the third, the question of publicising the results of research and putting them into practical application: there was a particularly lively discussion on the subject of patents.

The book now published by the O.E.E.C. contains the papers read and statements made at the Nancy Conference, as well as a very full account of the discussions that followed. These documents, which constitute a follow-up to the reports published in 1954 on the Organisation of Applied Research, are of interest to all persons concerned with the technical, managerial, financial or sociological aspects of scientific research.

Trade Publications

WE have received a copy of the latest edition of the Technical Survey published twice a year by the Copper Development Association. It gives a comprehensive review of recent technical developments in the production, properties and applications of copper and its alloys, with an extremely useful bibliography. A copy will be sent free to any reader who makes a personal application to the Copper Development Association at Kendals Hall, Radlett, Herts, with a request to be placed on the mailing list for future issues.

THE many uses of nickel and its alloys in electronic engineering are demonstrated by several abstracts appearing in the June–July issue of *The Nickel Bulletin*, which also refers to investigations on the physical properties of nickel, its use as a catalyst in the petroleum and other industries, and the characteristics of various compounds of nickel. In the electrodeposition section, there is a survey of papers presented at the Spring Conference of the Institute of Metal Finishing and at other meetings; a review of information on the influence of the basis metal on the properties of electrodeposited nickel coatings; and items relating to test methods and specifications. In the constructional steel section attention is directed to a comprehensive report on the fatigue properties of rolled alloy steels; and to an investigation of procedures suitable for welding high-yield-strength steels. The widening range of research on high-temperature materials is shown by abstracts relating to structural examination of high-temperature alloys; etching procedure; the use of such materials in industrial gas turbines; the mechanism of attack by vanadium pentoxide; methods of hot-ductility testing; and the nature and properties of cermets. Corrosion at elevated temperatures; stress-corrosion in stainless-steels; inhibiting media for addition to corrodents; and the use of Monel sheathing for protection of steel structures in sea water are among the specific aspects of corrosion on which information has recently been published. A list of revised U.S. stainless steel specifications is also given. This issue contains the usual quarterly survey of patent literature. Copies of *The Nickel Bulletin* are obtainable free of charge from The Mond Nickel Co., Ltd., Publicity Department, Thames House, Millbank, London, S.W.1.

WE have received from Imperial Chemical Industries, Ltd., Volume 1, Number 1, of a new monthly abstract publication produced by the Metals Division and dealing with titanium. It is described as a summary of published information on titanium and its alloys, and is divided into eight sections, dealing with properties and characteristics; alloys; metal fabrication; metal treatment and workshop practice; uses and applications; titanium compounds; general aspects; and bibliography.

Books Received

"A Study of the Iron and Steel Industry in Latin America": Vol. I—Report on the Meeting of the Expert Working Group held at Bogota; Vol. II—Proceedings of the Expert Working Group held at Bogota. Sponsored by the Secretariat of the Economic Commission for Latin America and the Technical Assistance Administration. 123 pp. Vol. I; 449 pp. inc. index, Vol. II. New York, 1954. United Nations, Department of Economic Affairs. Available from H.M. Stationery Office, Vol. I—9s.; Vol. II—32s. 6d.

"Protective Coatings for Metals." By R. M. Burns and W. W. Bradley. Second Edition. 643 pp. inc. author and subject indexes. New York and London, 1955. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 96s. net.

"A Handbook of Hard Metals." By W. Dawihl. (An abridged translation of "Handbuch der Hartmetalle".) 162 pp. inc. name and subject indexes. London, 1955. H.M.S.O. for D.S.I.R. 25s. By post 25s. 5d. (4 dollars 50 cents, U.S.A.).

"Aluminium Paint and Powder." By Junius David Edwards and Robert I. Wray. Third Edition. 219 pp. inc. index. New York and London, 1955. 36s. net.

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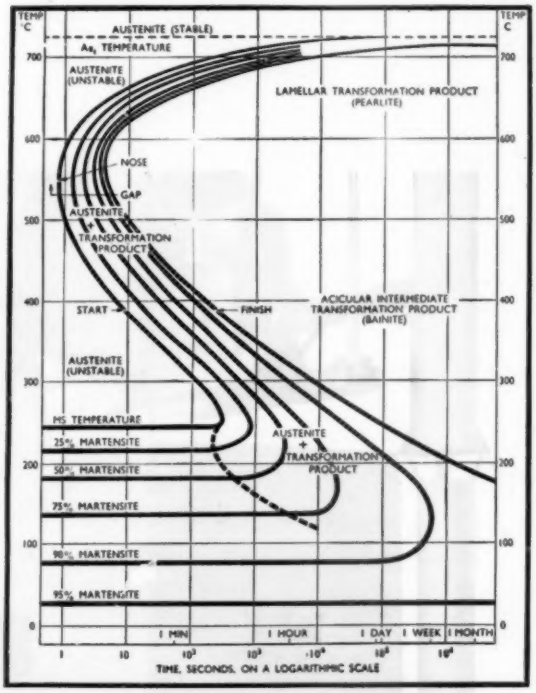

Modified Isothermal Transformation Diagram

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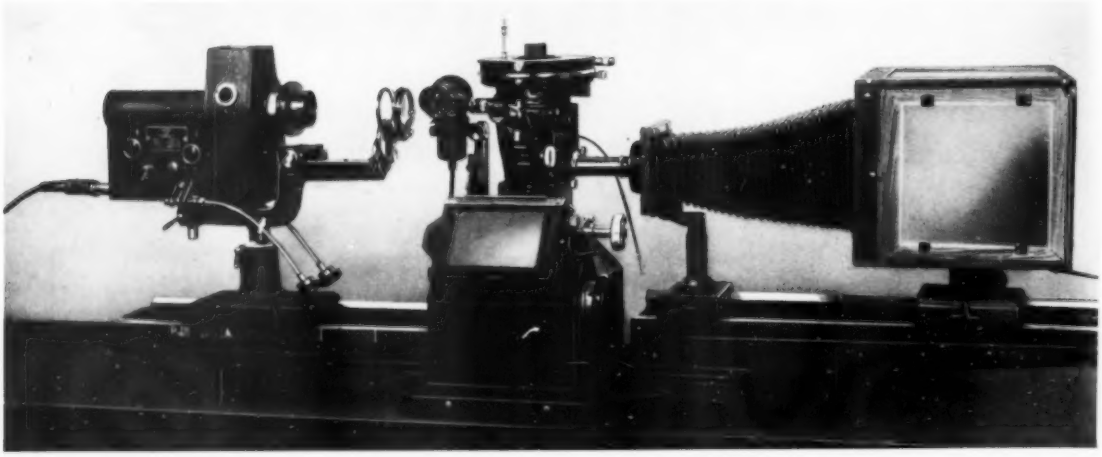

This is the new Reichert MeF-A Metallograph

The illustration shows the Reichert Universal Camera Microscope MeF-A with 13 × 18 cm Horizontal Mirror Reflex Camera and two 18 × 18 cm screens.

The new design of this microscope with its rigid all-metal optical benches has made it possible to combine in one instrument the advantages of the projection microscope with those of the large horizontal camera, which has an effective camera length of up to 90 cm. This arrangement makes the MeF a two-camera microscope, either camera becoming operative simply by turning a deflecting prism.

See this **REICHERT** *at the*

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LABORATORY METHODS
MECHANICAL • CHEMICAL • PHYSICAL • METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
SEPTEMBER, 1955 Vol. LII, No. 311

Vienna Microanalysis Congress

Abstracts of Papers of Metallurgical Interest

INCLUDED in the papers presented at the Microanalysis Congress, organised by the Austrian Society for Microchemistry and held recently in Vienna, were a number of interest to those concerned with metallurgical analysis. In the following pages an indication is given by means of abstracts, of the contents of such papers.

The Uses of Radioactivity in Microchemical Analysis.

By H Götte (Max Planck Institut für Chemie, Mainz, Germany).

A general treatment of radiochemical methods in analysis is given in this paper. All procedures for quantitative analysis which make use of radioactive species of atoms are essentially based on the radio-indicator methods introduced forty-two years ago by Hevesy and Paneth. The analytical procedures devised by these pioneers are of more general application to organic analytical problems at present. Dilution analysis, classed as the second main radiochemical method, can be of most value in series analyses under some circumstances. Finally, the third method, involving radioactivation of the material in an atomic pile, or in a suitable portable source of radioactivation, is the most useful for quantitative trace analysis of inorganic ions. All three procedures are characterised by high sensitivity and great specificity.

It is not practicable to give a fuller account of this paper here, because of the general nature of the subject matter, but the text will be published in full in *Mikrochimica Acta* in the near future. Readers wishing to obtain copies of the paper may do so by writing to the author at the above address. Copies of other papers may be obtained similarly.

The Technique of Paper Chromatography in Inorganic Analysis.

By M. Lederer (Institut du Radium, Paris, France).

Methods whereby inorganic substances can be determined by paper chromatography may be classified according to the solvent medium in which the determination is carried out.

(*A*) Those using solvents containing strong acids
(*B*) Those using solvents containing weak acids, bases or complex formers.
(*C*) Those using non-equilibrium conditions.

In the first category, solvents such as acetone/hydrochloric acid, butyl alcohol/hydrochloric acid, phenol/hydrochloric acid, and butyl alcohol/nitric acid are used. With these solvent systems it has been shown that for metals such as sodium, caesium, zinc, cobalt, iron, palladium, platinum, tin, barium and bismuth, the R_f values remain constant, even for the slightest traces of the elements. The method can, therefore, be used for carrier-free amounts. Similarly, there is the possibility of detecting traces by radioactivation techniques after isolation has been effected by chromatography.

The ion exchange properties of the paper are suppressed almost completely by the strong acid. Thus, a paper impregnated with cation exchanger Dowex–50 showed little change in R_f value from the usual Whatman No. 1 paper, when used with these strong acid solvents.

In certain cases, however, use can be made of complexes formed by the strong acids with certain cations. In 6M hydrochloric acid, ferric iron exists almost entirely as $FeCl^{4-}$, i.e., in the anionic state, whilst aluminium exists as a cation. This can be used for separation in several ways : (*a*) extraction from aqueous 6M hydrochloric acid with ether (the iron is removed to the extent of 99%, leaving the aluminium quantitatively behind) ; (*b*) paper chromatographically with butyl alcohol, 3N in hydrochloric acid (the hydration of the ferric iron is less in the alcoholic phase, and so 3N hydrochloric acid is sufficiently concentrated) ; (*c*) by adsorption of the $FeCl^{4-}$ on an anion exchanger, using 6N hydrochloric acid ; (*d*) by adsorption of the Al^{3+} on a cation exchanger ; and (*e*) by paper electrophoresis —the differently charged ions moving in opposite directions. Many other analogies are drawn by the author between paper chromatography and ion exchange. Over a range of acidities, ions such as the cupric and ferric ions can exist in several forms

$$Fe^{3+} \rightleftharpoons FeCl^{2+} \rightleftharpoons FeCl_2^{+} \rightleftharpoons FeCl_3^{\circ} \rightleftharpoons FeCl_4^{-}$$
$$Cu^{2+} \rightleftharpoons CuCl^{+} \rightleftharpoons CuCl_2^{\circ} \rightleftharpoons CuCl_3^{-} \rightleftharpoons CuCl_4^{2-}$$

Thus, it is possible, to choose the most suitable concentration of hydrochloric acid in the organic solvent to obtain a chromatographic separation, even between ions such as these.

In category *B*, the separation on paper depends on the same principles as those found in extraction under equilibrium conditions between free and complexed ions. Many separations may be carried out by having recourse to complexing agents such as acetylacetone. Naturally, extensive use is made of the large number of organic reagents which form complexes with various metal ions. These methods of separation on paper strips are, unfortunately, unreliable where large concentration differences exist, and it must be borne in mind above

all that the values of R_f constants are very readily affected by a number of factors.

In category *C*, the extraction of the uranyl ion from a spot of solution on the paper, by dry ether containing 2% nitric acid, is a typical example. The uranium moves with the solvent front, i.e., complete separation without absorption is obtained. The other ions remain adsorbed irreversibly on the dry paper. In this way the separation of an ion by specific extraction is possible. The use of two consecutive solvents may also lead to the separation of two extractable ions.

The Separation of Niobium and Tantalum by Paper Chromatography.

By E. Bruninx, J. Eeckhout, and J. Gillis (Laboratorium voor Analytische Chemie, Rijksuniversiteit, Ghent, Belgium).

The separation of niobium and tantalum by paper chromatographic methods on the micro-scale was examined by the authors. Various organic solvents were used as eluants, but the most satisfactory separation of the two elements was obtained with an eluting agent having the composition, 75% methyl ethyl ketone + 25% of 10M hydrochloric acid. The R_f values obtained were 0·11 for tantalum and 0·78 for niobium. The same eluant permits separation of titanium-niobium-iron or tantalum-niobium-iron, but by this method, titanium and tantalum cannot be separated. A semi-micro cellulose column was set up and good separations were again obtained using the same solvent system. The purity of the niobium obtained from diverse initial niobium/tantalum ratios was measured spectrographically, and two successive elutions yielded a product of 99·9% purity. With the cellulose column, 50 mg. amounts of mixtures of niobium and tantalum in ratios ranging from 25/1 to 1/1 were studied. Ninety per cent. of the niobium was recovered in the first 40 ml. of eluant, and it was not possible to detect tantalum in the first 30 ml. of solvent. The niobium and tantalum were used as oxalates.

It should be noted that details of a similar separation using hydrofluoric acid have been published by Mercer and Wells*.

The Microchemical Detection of Various Metals Using Ion Exchange Resins.

By H. Kakihana (Chemistry Department, Nagoya University, Nagoya, Japan).

A new technique for the identification of various ions is proposed by Dr. Kakihana. Slightly yellow or even colourless anion-exchange resins, e.g., Dowex 1 X–10–8–6 or Amberlite IRA 410–400, were used as the medium for the tests. By suitable choice of the resin and *p*H control a high degree of selectivity can be obtained whilst a high degree of concentration of the ion is obtained on the resin, even from very dilute solutions. Cobalt^{II} and chromium^{VI} can be detected by addition of ammonium thiocyanate and hydrogen peroxide, respectively. The change in colour of the small particles of exchange resin lying underneath the surface of the solution on the spot plate gives a very satisfactory identification. The limit of identification of the cobalt sky-blue complex is 0·16 γ and its limiting concentration is $1 : 1{\cdot}3 \times 10^{-5}$. The blue chromium colour gives an identification limit of 0·3 γ for this element, with approximately the same concentration limit. Germanium^{IV} can be detected by impregnating the resin particles with haematoxylin before adding them to the solution. By this method the identification limit for germanium is 0·005 γ. Interfering cations can be removed prior to the test by adding a suitable amount of powdered cation exchange resin, just before adding the anion resin. Other tests being examined by the author's colleagues include reactions such as those of vanadium^{V} with 8-hydroxyquinoline, aluminium with alizarin S, etc.

The Ring-Oven Technique.

By H. Weisz (Institut für Analytische Chemie und Mikrochemie, Technische Hochschule, Vienna, Austria).

This paper describes a remarkable innovation in spot-testing technique. If a drop of solution is spotted on paper and some of the ions in it are precipitated with a suitable reagent, such as hydrogen sulphide, these ions are localised. It is possible to wash out the soluble ones and identify them by other reactions further out in the paper. The main difficulty is the washing out of these soluble materials. Several washings are required and the soluble fraction is therefore spread over a wide area in the form of a broad ring round the original spot.

This difficulty is overcome by the new technique described by the author.† An electrically heated block carrying a 22 mm. aperture in the centre is used. The washed out fractions are carried out by the solvent to the edge of the aperture, where the solvent evaporates and the material is concentrated in a sharply defined ring no thicker than a pencil line. The area of this circle is no larger than that of the original spot and is frequently smaller. The paper is subsequently dried in a drying oven, the ring is cut into sectors with a pair of scissors, and then sprayed with various specific reagents. Thus it becomes possible to obtain separations on a single drop of solution.

To avoid enlarging the original spot of test solution, gaseous reagents are used wherever possible, being generated in a special apparatus. The paper is placed between the two halves of a cylindrical vessel and the gas is sucked through the paper by applying a small pressure difference. The material trapped in the original spot is dealt with by a similar technique. Thus, in the case where sulphides are fixed in the central spot, these are oxidised with bromine vapour and the spot is cut out with a cork borer. The small circle of paper is then placed in the centre of another filter paper on the ring oven and the materials are washed out into a ring on the second filter paper by applying solvent at the centre. The paper is then dried, cut into sectors and sprayed with various specific reagents, etc.

The ring oven method makes it possible to conduct semi-quantitative methods. A series of rings are prepared from standard solutions of the ion, and these rings are sprayed with the appropriate reagent. By comparing the ring of unknown concentration with the intensity of the ring from a standard series of known concentrations of the ion, it is possible to arrive at a surprisingly accurate measure of the amount of the substance present.

A Microvolumetric Method for the Determination of Barium Sulphate.

By H. Ballczo and G. Doppler (Chemische Laboratorium der Universität, Vienna, Austria).

Barium sulphate undergoes metathesis when heated with sodium metaphosphate at 1,000° C., with the formation of sodium barium phosphate and the evolution

* *Analyst*, 1954, **79**, 339.

† *Microchimica Acta*, 1954, 140, 376, 460

of sulphur trioxide. This method was used by the authors to bring barium sulphate into a form suitable for applying a titrimetric finish. The flux is treated with a measured excess of the complexone ethylenediamine tetra-acetic acid, and back titration of the excess is effected by addition of a standard magnesium solution (0.01–0·001M). As indicator, the *o*, *o'*-dihydroxyazo-dyestuff Eriochrome Black T was used, but the colour change of the indicator from blue to red-blue at the equivalence point was found to be somewhat vague, and a modified indicator was devised. The latter is prepared by adding Tropaeolin 00 dyestuff to the Eriochrome Black T. It is added in the solid form in a dispersion with powdered sodium chloride. A sharp colour change from green to red occurs at the end point.

In a method previously described by Belcher, Gibbons and West*, the barium sulphate is dissolved directly in ammoniacal ethylenediamine tetra-acetic acid, simply by boiling for 5 minutes, and the excess reagent is back titrated by a similar method.

A New Indicator for Titrations with Ethylene-Diamine Tetra-Acetic Acid.

By H. Flaschka and H. Abdine (Institut für medizinische Chemie and Pregl-Laboratorium der Universität, Graz, Austria).

These authors tested 1–(2–pyridyl azo)–2 naphthol (PAN) for suitability as an indicator in complexometric micro-titrations in an acetic acid medium. Because of the weak colour of some metal-PAN complexes, and because of the sluggishness with which some of them react, it is not advisable to titrate directly with ethylene-diamine tetra-acetic acid (EDTA). It is better to titrate back an excess of the EDTA with a standardised cupric solution. If one titrates to the rapidly established violet of the copper^{II}-PAN complex, a small indicator correction is necessary. However, if the violet solution is titrated back to yellow with complexone, no correction is then necessary, but, because of the sluggish reaction of the indicator complex, it then becomes necessary to work in hot solution. Titration in acetic acid solution permits working in the presence of the alkaline earth elements and low concentrations of manganese. A report is presented on methods for the determination of nickel, cobalt, zinc, cadmium, copper, lead and iron; aluminium cannot be determined. The same metals can also be titrated in ammoniacal solution, but in such a solution, magnesium, calcium and manganese partially displace copper from the EDTA complex, so that their determination also becomes possible. The advantage of this titration over that using Eriochrome Black T lies in the fact that the PAN indicator is not interfered with by traces of copper, iron, manganese, aluminium, titanium, etc. The titrations in acid and ammoniacal solution may be made in succession in the same solution, and it thus becomes possible to determine two metals one after the other, e.g., nickel-magnesium, zinc-manganese, or iron-calcium.

An excellent survey of titration methods using EDTA in ferrous and non-ferrous analysis, by E. G. Brown, has previously been published in this journal†.

The Absorptiometric Determination of Niobium with Tiron.

By H. Flaschka and E. Lassner (Institut für analytische Chemie der Technische Hochschule, Graz, Austria).

In this paper, a report is given of attempts to produce a coloured complex with niobium^{III}, although the desired result was not obtained. Tiron does form a coloured complex with niobium^{III}, but it is unstable towards aerial-oxidation. Niobium^{V} also produces a coloured complex, however, the deep yellow colour of which is stable in the range from about 5N hydrochloric acid to basic solution. A change in composition of the complex at higher *p*H values indicates structural changes in the molecule. The stability of the yellow colour in the acid region is dependent on the amount of hydrochloric acid and the concentration of Tiron, but both of these are easy to control. The colorimetric determination was carried out in a Lange colorimeter with a blue filter; it is interfered with only by vanadium^{V}, which forms an unstable blue complex. This interference can be eliminated by reducing with ascorbic acid. The mean error in determinations of from 2·5 to 8·5 mg. of niobium in 50 ml. of solution was 0·1 mg. No increase in the error was observed in the presence of three to four times as much tantalum, iron and tin.

The Microdetermination of Calcium using Loretin-Gravimetric and Spectrophotometric Methods.

By J. Gillis, J. van der Stock and J. Hoste (Laboratoire de Chimie Analytique, Universite de Gand, Belgium).

Loretin (7-iodo-8-hydroxyquinoline-5-sulphonic acid) was proposed as a reagent for the detection of calcium in 1932, and Schoorl developed a quantitative method for amounts of calcium not less than 5 mg. The method is an attractive one due to non-interference by the alkalis or magnesium, and to the very favourable conversion factor; but it is essential for its successful application that the initial calcium concentration should be not less than 2%. The present work is concerned with an improvement of the method to extend its use to smaller amounts of calcium at lower aqueous concentration. Whereas Schoorl attributed the formula $3[Ca(C_9H_4NISO_3H)_2].10H_2O$, to the complex, it has now been found to be more simply $Ca(C_9H_4NISO_3H)_2.3H_2O$. Precipitation of the calcium salt is complete over the *p*H range 3·7–5·9; the method does not, therefore, require precise control of acidity. Quantitative precipitation of calcium is only possible when the concentration is not less than 0·1 mg./ml., using an excess of a saturated solution of the reagent in 0·1 N sodium hydroxide. The excess necessary for complete deposition of the calcium corresponds to a tenfold amount, but as much as a 25 times excess may be tolerated. A more concentrated reagent solution is obtained if lithium carbonate is used in place of sodium hydroxide. It then becomes possible to determine calcium from a solution containing only 0·01 mg./ml. To obtain complete precipitation of the lithium it is necessary to let the solution stand for two hours after addition of the reagent. The drying temperature should not exceed 130° C.

The indirect spectrophotometric method involves re-solution of the calcium precipitate in an excess of standard ferric solution and measurement of the intensely green complex thus formed. The latter method was successfully operated with amounts of calcium of the order of 20 μg. with a mean error of 0·35%.

Micro-Methods for the Analysis of Semi Conductors.

By F. A. Pohl (Laboratorium der Allgemeinen Elektrizitätsgesellschaft A.E.G. Belecke/Möhne, Germany).

The electrical conductivity of semi-conductors is

* *Chemistry and Industry*, 1954, 127, 850
† *Analytica Chimica Acta*, 1954: **49**, 101, 151.

conditioned at normal temperatures, predominantly by the presence of foreign ions in the crystal lattice of the substance. Accordingly, conductivity data have meaning only when exact statements can be made regarding the purity of the material. The micro and trace analytical methods required for this are now available to only a slight extent, and the determination of non-metallic impurities or additions presents particular difficulty.

The conductivity of selenium is markedly influenced by halogens, and a description is given of a micro-method for the determination of chloride and bromide. The sample of selenium is dissolved in halogen-free nitric acid in the presence of a large excess of silver nitrate. The precipitated halides are reduced with hydrazine in caustic soda solution, and the silver is dissolved in nitric acid and titrated potentiometrically in a maximum volume of 0·5 ml. with 0·02 N thiocyanate solution, using a Gorbach membrane burette. Bromine is determined photometrically as tetrabromofluorescein, and the chloride content calculated from the two results. As little as 0·0001% halogen can be determined by this method.

THE ABSORPTIOMETRIC DETERMINATION OF NICKEL WITH SODIUM DIMETHYLGLYOXIME.

By W. NIELSCH and L. GIEFER (Kontrall Laboratorium der Riedel-de Haen Chemische Fabriken, Seelze, Hannover, Germany).

Very small amounts of nickel can be precipitated as the well known nickel dimethylglyoxime compound by using the water soluble sodium dimethylglyoxime reagent described by the authors. Amounts of nickel varying from 10–130 γ in 1–13 ml. of solution were treated with 2 ml. of 10% sodium tartrate and 10 ml. of 5% reagent. The ammoniacal solution was shaken with 30 ml. of chloroform for 1 minute and the chloroform layer was separated off and dried over anhydrous sodium sulphate. The absorbancy of the dry extract was measured in the 360–380 mμ waveband. The method has been used for the determination of nickel in iron-containing compounds. The first extraction is carried out from a medium containing a much greater amount of tartrate, but instead of drying the extract, the chloroform layer is shaken up with a solution containing hydrochloric acid, tartrate, dimethylglyoxime etc., to withdraw traces of iron from the chloroform layer, and the latter is then dried and carried through the normal procedure.

A NEW MICRODETERMINATION OF BISMUTH.

By M. OOSTING (Institüt für Analytische Chemie. T.N.O. Rijswijk, Holland).

Bismuth can be determined by extraction of the brucine-bismuth-iodide complex from aqueous solution by means of chloroform. The measurement of the absorbancy of the extract at 425 red mμ gives a sensitive method of determination, very few ions interfering. Cadmium causes low results, and high results are caused by trivalent antimony and stannic tin. When interferences occur, the bismuth is first extracted with diethyldithiocarbamate at *p*H 11–12 in the presence of potassium cyanide and EDTA. This separation succeeds, even when very large amounts of interfering ions are present, e.g., copper, lead, etc. The extract is evaporated in a beaker containing 2*N* sulphuric acid, whereby the chloroform is evaporated and the diethyldithiocarbamate is destroyed. The bismuth is then extracted from the aqueous layer and determined as described previously.

THE LIMIT OF DETECTION IN SPECTROCHEMICAL ANALYSIS.

By H. DE LAFFOLIE (Institüt für physikalische Chemie der Universität Münster Westfalen, Germany).

A limit is set for the detection of a spectral line by the fact that the line radiation issuing from the light source is overlaid by continuous background radiation; with decrease of intensity, the line sinks into the background. This point is determined basically by the characteristics of the emulsion used and, in fact, by the granularity distribution and the gradation. By using the Seidel transformation it has been shown how granularity distribution and gradation can be employed to determine the relation of intensity of line and the background at which the line is just emerging. The relation is given numerically for several emulsions that are frequently used.

SPECTROGRAPHIC TRACE DETERMINATION OF LEAD SUBSEQUENT ON INNER ELECTROLYSIS.

By W. SEITH and W. GREMM (Institut für physikalische Chemie der Universität Münster, Westfalen, Germany).

A method is described for the spectrographic determination of lead in trace amounts after the latter has been concentrated by deposition on cadmium metal as a result of internal electrolysis. A rotating electrode was used for sparking-off, and when tin was used as reference element, the mean error obtained by this method was ±9% of the analytical value.

THE SPECTROGRAPHIC ANALYSIS OF SILICON CARBIDE.

By F. ROST (Institut für Mineralogie, Technische Hochschule, München, Germany).

The fundamental principles underlying the spectrographic determination of various impurities in silicon carbide are discussed in this paper. The results obtained show the superiority of the spectrographic method in the relative determination of aluminium, iron, titanium and magnesium, as compared with chemical methods. This analysis can be conducted by a simple method with a mean error of 7–15%. It is possible to state the absolute content in order of size.

The analytical results quoted by the author of this paper show a distinct dependence of the properties of the silicon carbide on the aluminium content. These properties may be modified by the presence of either extremely high or low values of iron and titanium.

THE INFLUENCE OF FOREIGN IONS IN FLAME PHOTOMETRY.

By J. FISCHER and A. DOIWA (Institut für anorganische Chemie, Frankfurt-am-Main, Germany).

Whilst flame photometry is an excellent and sensitive method for the determination of the alkali metals in admixture, it demands most careful consideration of the influence of cosolutes. In addition to secondary interferences (foreign light, alteration of the atomising conditions, etc.) which are readily eliminated, real interferences occur because of changes brought about in dissociation and ionisation in the flame. The great influence of the temperature and the concentration of the solution on the error arising from the cosolutes is discussed by the authors.

THE SEPARATION OF MICRO-AMOUNTS OF INDIUM FROM ZINC BY EXTRACTION.

By L. KOSTA and J. HOSTE (Laboratory for Analytical Chemistry, University of Ghent, Belgium).

A separation procedure based on the extraction of indium bromide by diethyl ether is not practicable in

Continued on page 153

Exhibits of Metallurgical Interest at the Physical Society Exhibition

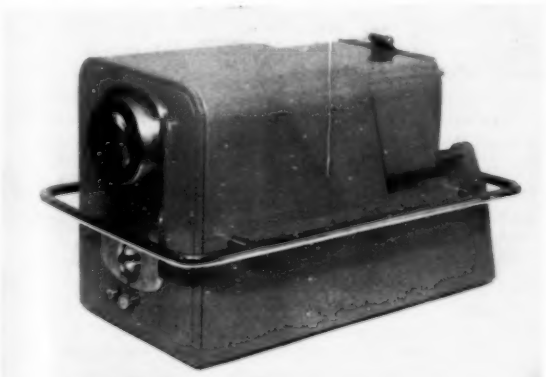
The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

High Speed Camera

THE optical system used in the Courtney-Pratt Series C.600 high speed camera shown by J. Langham Thompson, Ltd. enables a series of photographs to be taken at a speed far greater than has hitherto been possible for such simple and versatile equipment*. This result has been achieved by the aid of an assembly of small lenses embossed in plastic and bonded to a glass plate. The lenses dissect the picture into a large number of small elements, each set of picture elements being recorded simultaneously on the photographic plate with a spacing between adjacent elements that is large compared with the size of each element. The displacement of the picture element is produced by altering the direction in which light falls upon the assembly of small lenses, this being achieved by using a Nipkow disc.

The complete series of pictures is recorded on an ordinary photographic plate and, after processing, the plate is replaced in the film carrier in order to examine the high speed phenomena at slow speed, or to take individual pictures of interesting characteristics. After replacing the photographic plate in the holder, a bright light source is introduced into the main camera lens which produces silhouette pictures on a ground glass screen situated at the rear of the film carrier. This process may be reversed when convenient, and the event displayed on a screen situated in the position that the object adopted whilst being photographed. The rotation of the Nipkow disc will show on the ground glass screen the series of photographs that was recorded at high speed. The aperture disc may be stopped in any desired angular position and simple contact prints taken of the event in its various stages of development.

* J. S. Courtney-Pratt. Fast Multiple Frame Photography, *Journal of Photographic Science*, 1953, 1, 21.



Courtney-Pratt Series C.600 high speed camera

In this way the completed record is " unscrambled " for analysis.

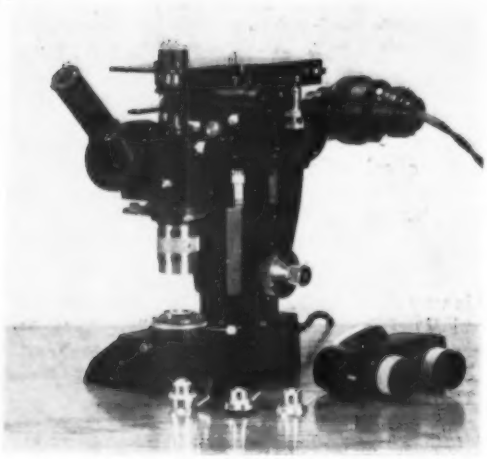
This new method enables pictures to be taken at rates in excess of 100,000 pictures per second, and 200 discrete pictures may be recorded. Each picture is dissected into 80,000 elements and these give an equivalent resolution of 250 lines across the film plate in each direction. As a comparison, the overall resolution may be compared with a normal type 16 mm. photograph. The versatility of this new method makes it suitable for the study of many rapidly occurring phenomena, and the system is already being used in connection with studies of combustion, detonation, vibration and fracture, electrical discharges, in many branches of ballistics, and in many other fields of research.

Inverted Metallurgical Microscope

The instruments shown by Cooke Troughton and Simms, Ltd., included a fully equipped bench type microscope, capable of all the modern techniques employed in metallurgical research, and based on the Le Chatelier principle. The stand is of robust construction, with the focusing controls near the base of the instrument, the coarse and fine motion controls being concentric. The fine focusing movement, which can be read to one micron, is applied to the objective and its support only, while the coarse movement actuates the limb upon which the mechanical stage is mounted. The inclined binocular eyepiece (interchangeable with other types of body) is carried directly from the central pillar, together with the reflector body, a lamp, and a camera attachment. The fine focusing movement is thus relieved of the greater portion of the load normally associated with it, thereby obviating flexure and instability which otherwise would affect the objective setting. The lamp attachment houses a 6-volt 48-watt solid source filament lamp with focusing and centring controls, but is readily removable so that alternative external sources of illumination, such as mercury vapour or arc lamps, can be attached to the base.

The instrument can be equipped for any or all of the following systems : (*a*) normal incident illumination ; (*b*) dark ground illumination with catoptric condenser ; (*c*) phase contrast for incident light, incorporating positive and negative phase contrast, normal incident and dark ground illumination ; (*d*) micro hardness testing ; (*e*) polarised light ; and (*f*) the Tolansky techniques for the study of minute irregularities in the surfaces of crystals and of machined, ground or lapped metal surfaces. Photomicrography can be undertaken by means of an attachable 35 mm. single exposure camera or alternatively ¼ plate bellows camera on a separate stand upon which the microscope is mounted.

The Tolansky techniques referred to under (*f*) include : (1) a high resolution surface profile technique : this is



Inverted metallurgical microscope

a modification of the Schmaltz light slit method and is suitable for opaque specimens in which a bright field image is crossed by one or a series of parallel lines to yield in the latter case a multiple profile picture ; (2) a simple interference method, suitable for opaque specimens, whereby a series of interference fringes are formed between a reference surface and the surface under test ; (3) multiple beam interferometry for transparent or opaque objects, whereby a series of very narrow Fizeau fringes are formed between a reference surface and the surface under test ; and (4) fringes of equal chromatic order for transparent or opaque objects, whereby the optical separation between the reference plate and the surface of the specimen can be accurately determined, even when the fringes are discontinuous.

High Precision Disappearing Filament Pyrometer

Attention was drawn to the limitations in precision of many types of disappearing filament optical pyrometers in a paper* published by C. R. Barber of the National Physical Laboratory in 1945. These were shown to be due to defects of design of the pyrometer lamps and of the optical systems, and to the deflection instruments used to indicate temperature. Subsequently, Barber, in collaboration with the British Iron and Steel Research Association, designed a high precision disappearing filament pyrometer, which has been further developed by Tinsley (Industrial Instruments) Ltd., by whom it is now manufactured under licence. This instrument was shown by Eversheds and Vignoles, Ltd. with whom the Tinsley company is associated.

* *Jnl. Iron and Steel Inst.*, 1945, 152, 171.

High precision disappearing filament pyrometer

The pyrometer is self-contained except for the small dry battery, which is installed in the carrier case or can be conveniently carried in a pocket. The body is of light alloy, anodised and dyed black, and the front extension tube, which supports the objective lens, provides a comfortable hand grip. A balanced bridge circuit measures the resistance of the comparison filament, and hence indicates its brightness temperature with great accuracy. Rapid operation is made possible by interlocking the lamp and bridge currents so that the bridge current is automatically maintained approximately in balance as the lamp current is adjusted. The bridge current rheostat and slide wire contact are adjusted by a single knob. Interlocking keys are provided to prevent accidental overloading of the galvanometer.

The optical system comprises a telescope with the proper entrance and exit angles to ensure a bright field and good disappearance of the filament when a brightness match is made. A neutral filter is inserted in the optical system when the higher of the two temperature ranges is required. Monochromatic vision is provided by a carefully selected colour filter. The lamp has a flat tungsten filament of very small thermal inertia, and of sufficient length to eliminate ambient temperature errors resulting from end effects. Three models are available, covering, in two temperature ranges in each case : (*a*) 800–1,900° C. ; (*b*) 800–2,300° C. ; and (*c*) 1,100–3,600° C. The limits of accuracy vary from ±5° at 800–1,250° C. to ±30° C. at 3,000–3,600° C., with reproducibility of reading of ±2° C. at 1,250° C., ±4° C. at 2,000° C., and ±10° C. at 3,600° C.

The pyrometers are normally calibrated against a tungsten strip lamp standardised by the N.P.L., and a certificate stating the corrections is issued with each instrument. If required, a direct calibration by the N.P.L. can be supplied.

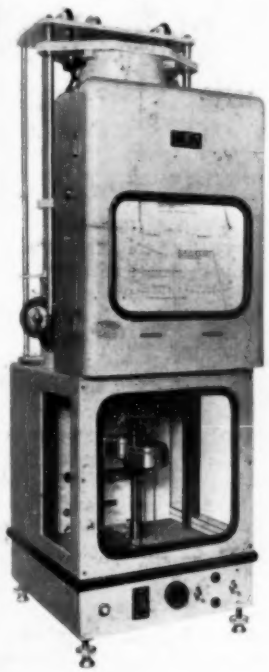
Thermobalance

The thermobalance shown by Stanton Instruments, Ltd., simultaneously and continuously records change of weight, temperature and time. The main balance is of conventional three knife edge type, but functions as a constant load instrument. A bifilar nickel-chromium alloy wound furnace of 2 in. internal bore is arranged above the balance. The furnace shown at the Exhibition is suitable for 1,000° C., and a platinum wound high temperature furnace will be available shortly. The furnaces on both models are designed for use with inner sheaths when it is desired to heat the charge in either a gas or a corrosive atmosphere. A simple but effective combined programme and limit control, which works in conjunction with variable high/low switching, is fitted. The standard programme cam gives a linear rate of heating, and alternative cams are available to suit customers' own requirements.

The object, whose change of weight it is required to follow, may be placed either on the lower pan or on a silica platform located in the furnace and mounted on a silica rod which rises from the rear suspension piece of

the balance. Furnace temperature and change of weight are followed simultaneously on a twin pen electronic recorder fitted above the balance and in front of the furnace. The curves are seen at eye level and are both shown by continuous lines side by side. The twin pens are power driven by servo-motors, and receive their information from a platinum/platinum-rhodium thermocouple and a capacity follower plate located over the balance beam. This plate faithfully follows every minute movement of the beam, yet has no direct or mechanical contact with it. Thus, the balance may be arranged when manufactured for either 1 mg. sensitivity, such as the model shown, or for 0·1 mg. sensitivity with the same proportional accuracy of scale.

The ability of this instrument to record change of weight is limited neither by the range of the chart nor by the range of the single beam deflection. Advantage



Thermobalance for recording change of weight on heating

is taken of the servo-driven mechanism to operate electric weight loading at the end of each full beam movement. By this means it is possible to follow weight change up to ±1 g. automatically. The instrument, once set, will reproduce and record time, temperature and weight changes for several days.

In the field of gravimetric analysis the uses of this instrument are many and varied. For example, the analyst obtains a permanent record of an ignition or similar study, and may at his leisure decide when his precipitate reached constant weight: it is equally suitable for research into analytical work and control work. Its further uses include the determinations of moisture, volatiles and ash; the preparation of oxidation curves for high temperature test pieces, including sintered metal compacts, ceramics, etc.; the behaviour of desiccants, solvents and catalysts, etc.; and the investigation of sublimation, surface absorption, reagent purity and atomic weights.

Vienna Microanalysis Congress

Continued from page 150

the presence of zinc. Over a wide range of metal ion and hydrobromic acid concentrations, zinc is extracted with the indium to the extent of 9%. Further work showed the possibility of such a separation when ethyl ether is replaced by *iso*-propyl ether. The extractability of zinc bromide in this solvent is negligible in the acidity range 0·5–6M hydrobromic acid. The results obtained by activity measurements during the extraction of indium 114 revealed that quantitative separation of the indium is obtained in a single extraction from 6M hydrobromic acid. The alteration in phase volumes during extraction is very small in comparison to those usually observed with diethyl ether and 6M hydrobromic acid.

Because of its simplicity and efficiency, this separation method could prove very convenient in the analysis of metallic zinc and zinc concentrates, in which indium is to be determined.

The Determination of Micro Amounts of Indium in Zinc and Gallium by Radioactivation.

By J. Hoste and H. van den Berghe (Laboratory for Analytical Chemistry, University of Ghent, Belgium).

A 1 g. radium-beryllium thermal neutron source was used by the authors for the purpose of activation. By activation of an amount of 10 g. of zinc for 5 hours and counting the activity in a well-type sodium-iodine scintillation counter, 17·4 counts/sec./10 g. zinc were obtained. Activation of indium under identical conditions gave 28·9 counts/sec./10 mg. metal. It was, therefore, possible to determine amounts of indium varying from 0·004%–0·16%, in zinc, using 10 g. samples, with a mean error of 2·3%, without chemical separation. To determine traces of indium in gallium, a chemical separation is required. One gram of metallic gallium gave an activity of 115 counts/sec. The activation of the gallium/indium samples is carried out in a solution of their sulphates. After activation, the solution is treated with potassium iodide and sulphuric acid to make it 2M with respect to hydroiodic acid, and the indium iodide is extracted with ethyl ether and counted in a vial fitting the well-type counter. Using 0·5 g. gallium samples, it was possible to determine indium amounts down to 0·2 mg. with a mean error of about 5%.

Laboratory Furnishing Contracts

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The Spectrochemical Determination of Magnesium and Beryllium in Aluminium Alloys Using a Rotating Disc Electrode

By N. Haigh

Aluminium Laboratories Limited, Banbury.

A spectrochemical method for the analysis of small amounts of magnesium and beryllium in aluminium alloys is described. The samples are dissolved in acid and examined by the rotating disc technique using a Hilger Medium Quartz spectrograph and uncontrolled spark source. The method is simple and less tedious than the existing chemical methods.

ONE of the fundamental difficulties of spectrographic analysis in a metallurgical laboratory is the problem of obtaining standards of similar form and composition to the samples submitted for analysis. In a production laboratory this problem largely centres on ensuring that the electrodes used are analytically homogeneous and metallurgically sound. In a research laboratory, however, a further problem is presented by the fact that samples are submitted for analysis from many sources, may be in almost any metallic form, and may have a varied metallurgical history. A method which permits the accurate analysis of these samples without regard to their source or metallurgical structure presents obvious advantages. A method in which the sample is reduced to a solution not only offers these conditions but also an important advantage in regard to standardisation. Spectrographic analysis by the more conventional methods, i.e., pin electrodes or discs with a metallic or pure graphite counter-electrode, is only a secondary method, being entirely dependent on the chemical analysis of the standards used for the evaluation of unknown samples. By using solutions as the basis for the standardisation, synthetic standards can be prepared from pure chemicals, which makes the method independent of chemical analysis. This is particularly advantageous when preparing spectrographic methods for the analysis of elements which are difficult or unsatisfactory to determine chemically. The present chemical methods for the determination of small amounts of magnesium and beryllium in aluminium alloys are typical examples.

Of the solution methods investigated, the two which involve the minimum amount of sample preparation are the porous cup method of Feldman[1] and the rotating disc technique developed by Pierucci and Barbanti-Silva[2], both of which employ direct excitation of the solution.

The rotating graphite disc technique has been used with various modifications by Gambrill, Gassmann and O'Neill[3] and by Pagliossotti and Porsche[4–6] for the determination of impurities in lubricating oils and cracking catalysts, by Rouir and Vanbokestal [7] for the analysis of copper alloys, and by Hugo[8] for the determination of magnesium in cast iron, while a more recent method using a silver disc electrode for the analysis of lake waters is described by Meloche and Shapiro[9]. To our knowledge, however, there has, as yet, been nothing published on the application of this method to the analysis of aluminium alloys.

Apparatus

An attachment was constructed similar in principle to that made by Applied Research Laboratories[10–12], but adapted for use with the Hilger spectrograph (see Figs. 1 and 2). A small synchronous motor rotating at 12

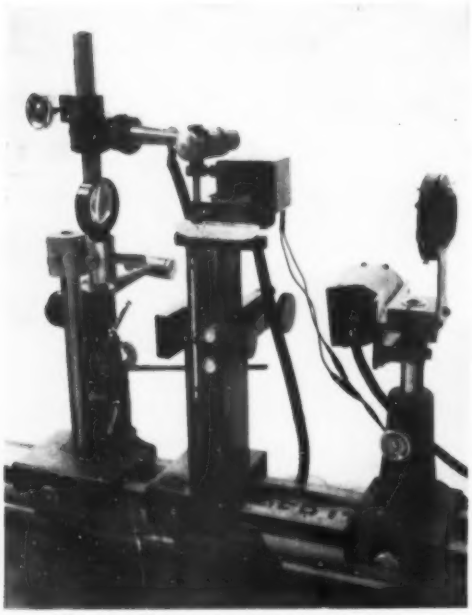

Fig. 1.—Rotating electrode attachment.

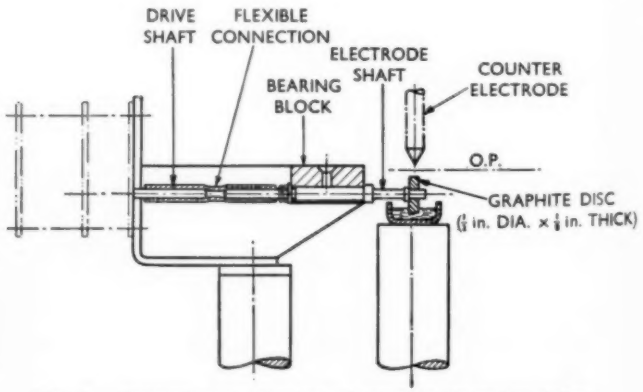

Fig. 2.—General arrangement of rotating electrode drive

r.p.m. is connected by a flexible rubber coupling to a stainless steel shaft to which is attached a graphite disc $\frac{1}{2}$ in. diameter by $\frac{1}{8}$ in. thick. The disc has a central hole $\frac{1}{8}$ in. in diameter which is a push fit on to the shaft, and is located horizontally in the optical plane by a small shoulder. The whole driving assembly can be raised or lowered for vertical alignment. Electrical contact to the disc is made through the bearing, which is isolated from the motor by two Tufnol supports and the rubber coupling. The solution under examination is held in a silica combustion boat placed on the forward platform and raised until the disc is dipping into the solution. The upper electrode is a $\frac{1}{4}$ in. diameter graphite rod turned to a 60° cone.

General Procedure

The following procedure has been used for the determination of magnesium and beryllium in aluminium. Similar methods can be used for other metallic impurities, but are unsuitable for elements such as silicon, which tend to be precipitated in acid solution.

Dissolve 1 g. sample in 25 ml. 1 : 1 hydrochloric acid, reduce the volume to 10–15 ml., cool and make up to 25 ml., returning the sample to the original beaker. Transfer part of the sample to a silica combustion boat and place on the platform of the solution apparatus. Raise the platform until the disc is rotating in the solution at a depth of approximately $\frac{1}{16}$ in. The same disc can be used for all exposures of the same sample, but the counter-electrode is changed for each exposure. In order to make the periphery of the disc more porous, prespark for 30 seconds before the first exposure and for 10 seconds before each subsequent exposure.

When any difficulty was met in dissolving the original sample, as in the case of super-purity aluminium, a mixture of 5 g. mercuric chloride in 1 litre of 1 : 1 hydrochloric acid was used for the initial attack.

Preparation of Standard Solutions

Standard solutions of impurities were prepared in hydrochloric acid whenever possible. These were added to a matrix of aluminium which was either in the form of metallic aluminium of known composition, dissolved in 1 : 1 hydrochloric acid as above, or as a solution of aluminium chloride. When preparing working curves, the standards were sparked three times on at least three plates.

The graphite electrodes used were supplied by Messrs. Johnson Matthey, Ltd., the upper electrodes being grade 4B, which contains approximately 0·5 p.p.m. of magnesium, the discs having approximately 0·2 p.p.m. As these values are very small and, for all practical purposes, reproducible, no correction has been applied.

Analysis of Aluminium for Magnesium and Beryllium

Magnesium

Small amounts of magnesium are generally found in aluminium alloys, even when it is not an added constituent. The amount present is usually less than 0·01%, but it is occasionally necessary to determine a definite value in standards or non-routine samples. Chemical methods for small amounts of magnesium are rather tedious and subject to error, and the present method has been devised as an alternative.

The determination of magnesium in unalloyed aluminium (Noral 2S) and in an aluminium—1¼% manganese alloy (Noral 3S) was carried out using the conditions shown in Table I. The working curves prepared by plotting log. intensity ratio Mg 2852/Al 3050 versus log. concentration are shown in Fig. 3.

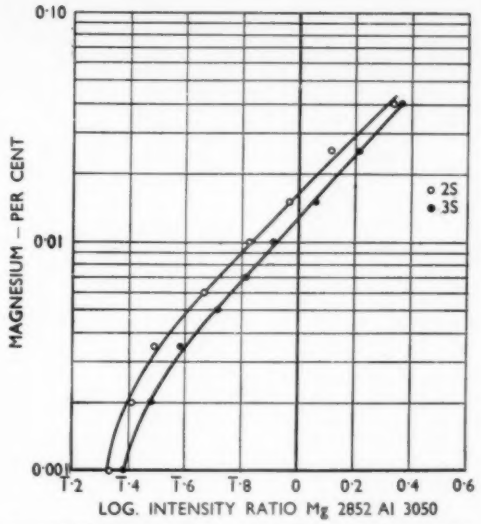

Fig. 3.—Calibration for magnesium in Noral 2S (open circles) and 3S (full circles).

TABLE I.—CONDITIONS USED FOR DETERMINATION OF MAGNESIUM IN NORAL 2S AND 3S

Spectrograph	Hilger Medium Quartz
Source	Hilger Simple Uncontrolled Spark
Voltage	15,000 volts
Inductance	0·06 millihenry
Capacity	0·005 microfarad
Spark Gap	3 mm.
Source to Slit	38 cm.
Slit Width	0·025 cm.
Pre-spark	30 : 10 : 10 sec.
Exposure	45 sec.
Plate Type	Kodak B10
Developer	D19, 3 min. at 20° C.

Emulsion calibration was carried out by the rotating step sector method using two pure iron electrodes.

Beryllium

Beryllium is now frequently added to the aluminium-magnesium alloys, either in lieu of a flux or to avoid mould reaction, but the chemical determination of beryllium in aluminium is extremely tedious and rather uncertain. A solution method for the spectrographic analysis of beryllium in aluminium-magnesium alloys has been described by Gusyatskaya and Rusanov[13], but as this method also employs a special lower electrode assembly it was decided to investigate the technique already available.

Calibration for beryllium from 0·001 to 0·50% in an aluminium–10% magnesium alloy (Noral 350) was carried out in two stages, i.e., 0·001 to 0·035% and 0·03 to 0·50%. The conditions used for magnesium were modified slightly in order to obtain suitable line densities. For the lower range an Ilford Thin Film Half-Tone plate was used instead of Kodak B.10, and for the higher range the exposure time was reduced from 45 seconds to 20 seconds. The line pairs used were Be 3130/Al 2660 and Be 2651/Al 2652, respectively. The working curves are shown in Fig. 4. It has not been necessary for the author to calibrate below 0·001% beryllium, but this should not be difficult as Be 3130 is extremely sensitive.

Precision

The precision of the method is illustrated in Tables II and III. Reproducibility tests were carried out for magnesium at 0·01% and for beryllium at 0·005, 0·02

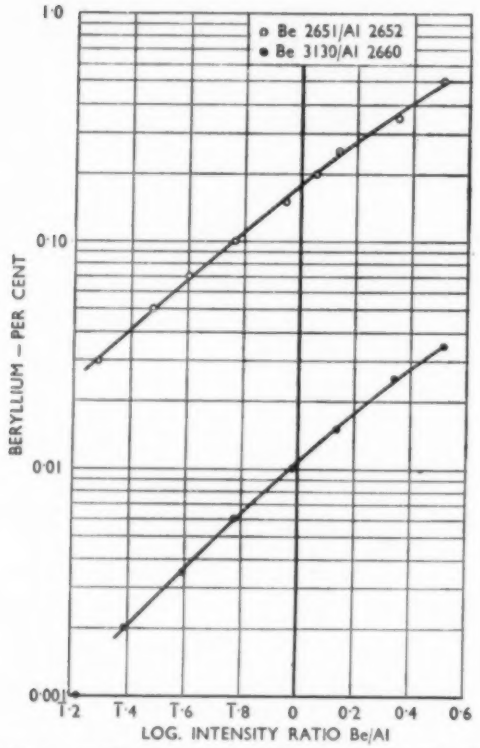

Fig. 4.—Calibration for beryllium in Noral 350 alloy.

and 0·20%. These tests were done both on a single solution and on a series of solutions. Comparison between this method and chemical methods is difficult owing to lack of corresponding data, but reference to the literature, and particularly to the papers of Scheuer and Smith[14] van Someren[15] and Hermon and Mills[16, 17] suggests that the method described here is as good as, if not superior to, the present chemical methods.

Discussion

The method described in this paper has been used, with various modifications, for a variety of problems of which the above are typical. In general, satisfactory results have been obtained, but some improvements are possible. For example, the stainless steel shaft to which the disc is attached is subject to some attack from hydrochloric acid solutions and has to be changed at

TABLE II.—REPRODUCIBILITY TESTS FOR MAGNESIUM IN NORAL 28 AND 38[a]

	% Mg	28			38		
		σ	v	n	σ	v	n
Between Samples	0·01	0·00044	4·4	24	0·00071	7·1	24
Within Sample	0·01	0·00016	1·6	24	0·00042	4·2	24

σ = Standard deviation.
v = Coefficient of variation.
n = Number of observations.

[a] The following formula was used for the evaluation of the data in Tables II and III

$$\text{Coefficient of variation} = \frac{100}{C}\sqrt{\frac{\Sigma d^2}{n-1}}$$

where C is the concentration, per cent.,
d is the difference of the determination from the mean, and
n is the number of determinations.

TABLE III.—REPRODUCIBILITY TESTS FOR BERYLLIUM IN NORAL 350 ALLOY[a]

	% Be	σ	v	n
Between Samples	0·005	0·00036	7·2	23
Within Sample	0·005	0·00029	5·8	27
Between Samples	0·02	0·0012	5·8	23
Within Sample	0·02	0·0011	5·7	27
Between Samples	0·20	0·008	4·0	23
Within Sample	0·20	0·011	5·6	27

σ = Standard deviation.
v = Coefficient of variation.
n = Number of observations.

frequent intervals, as the discs fail to fit tightly when the shaft becomes slightly corroded. This is now being replaced by a shaft with a platinum-rhodium end piece.

The use of a pure metal counter-electrode to replace the pointed graphite rod is also being considered, with the object of reducing the background due to cyanogen bands at the higher wavelengths.

It is essential that the depth of immersion of the disc should be maintained at a constant level for each group of determinations. Meloche and Shapiro[9] found large variations of intensity ratio with variations of depth of immersion when analysing lake waters. In practice, however, it is not difficult to approximate a depth of $\frac{1}{16}$ in., as the distance between the central hole and the edge of the disc is only $\frac{3}{16}$ in.

Acknowledgment

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